Materials Engineering in Product Design & Manufacture

Materials & Methods

April 1954

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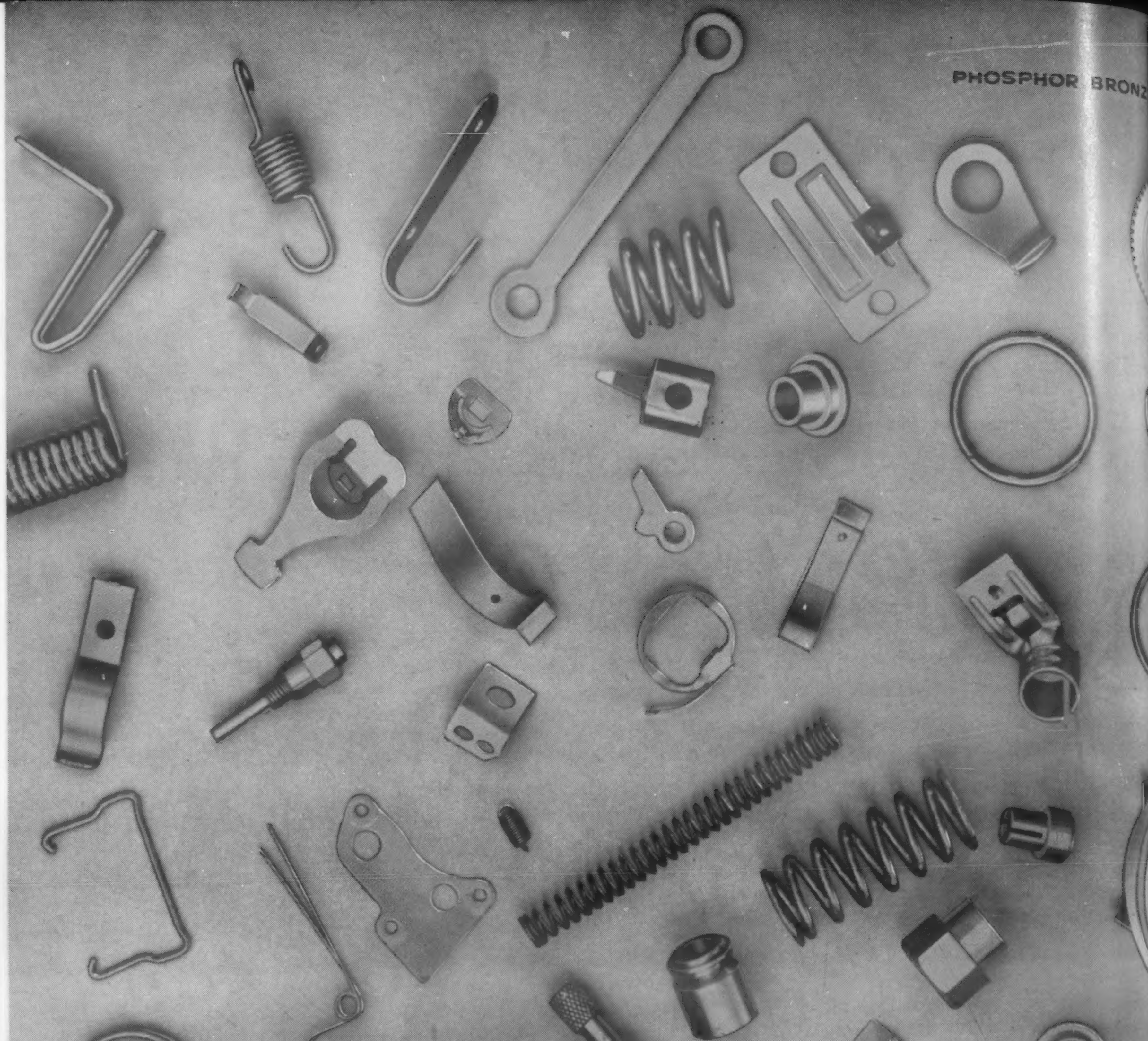
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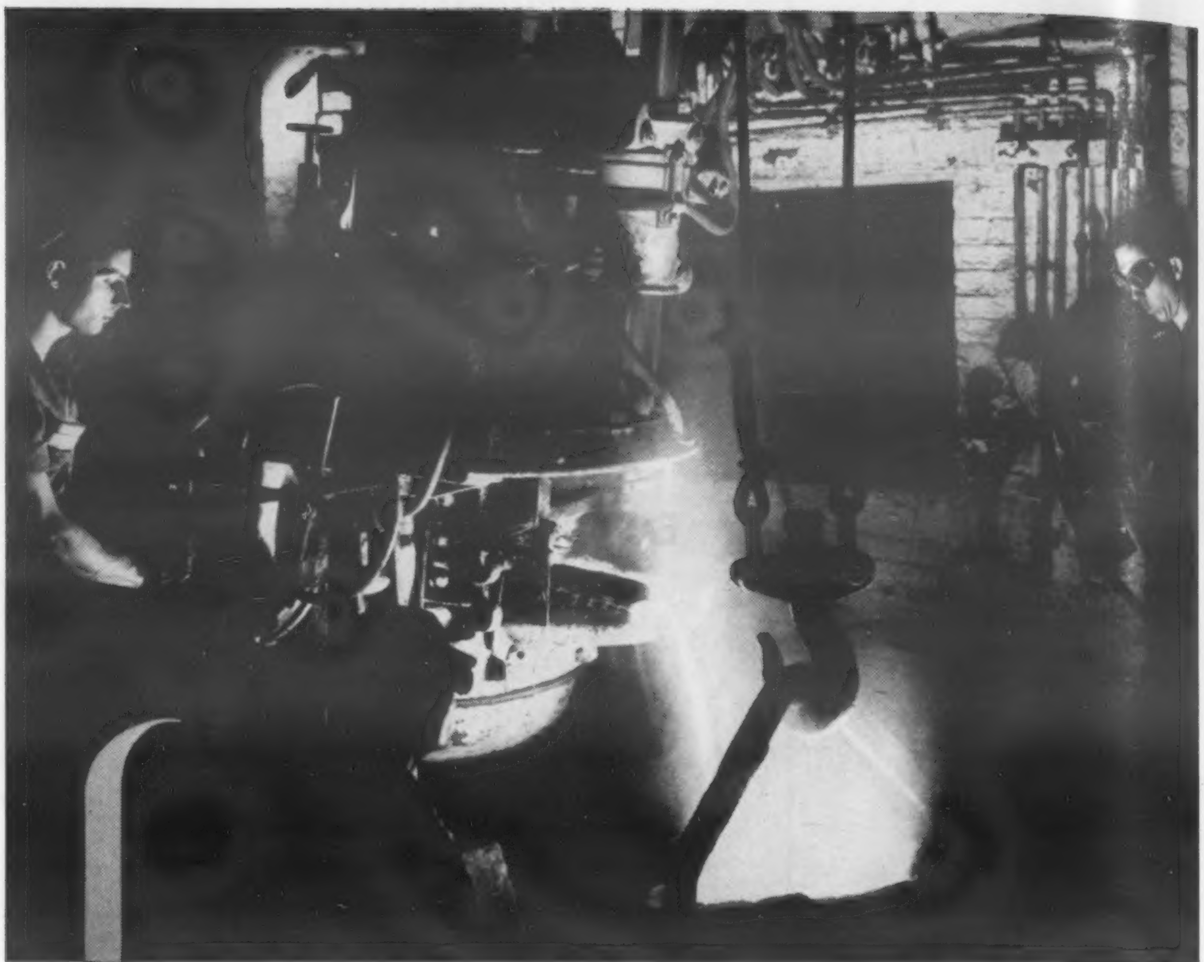
MATERIALS & METHODS IS INDEXED REGULARLY IN THE ENGINEERING INDEX AND THE INDUSTRIAL ARTS INDEX

Materials Engineering in Product Design & Manufacture

Materials & Methods.

APRIL 1954 **VOL. 39, NO. 4**



The Materials Outlook

ELECTROLYTIC CHROMIUM

Commercial production of electrolytic chromium is now underway. Output of Electro Metallurgical's Marietta, Ohio, plant is expected to be about 2000 tons a year when full production is reached. Most of the high-purity metal will go into nickel- and cobalt-base high-temperatures alloys. It may also be useful in making ductile chromium, chromium carbide and other materials.

MOLDED POLYSTYRENE FOAM

An expandable polystyrene that can be foamed in a mold is now commercially available. The new material is supplied in the form of free-flowing, small polystyrene beads impregnated with a special foaming agent. Densities ranging from 2 to 10 lb per cu ft can be obtained by varying the quantity of beads placed in the mold. The foamed plastic has a closed cell structure and a high-density skin. (Complete story in this issue.)

NEW REINFORCED PLASTICS

Data on a new family of reinforced plastics for electrical applications are expected to be available shortly. These are diallyl phthalate polyester resins reinforced with cotton, glass, nylon or Orlon. The DAP-Orlon combinations are reported to show special promise.

CLOSE TOLERANCE SAND CASTINGS

An instrument plant has found it possible to hold tolerances of 0.003 to 0.005 in. on core sections of large sand-cast aluminum and magnesium parts.

RIGID POLYETHYLENE

Availability of a new polyethylene resin has made it possible to mold rigid housings and other parts that are no thicker than the "squeezable bottles" made with more flexible resins.

POLKA-DOT PAINT

That old gag about polka-dot paint is not a gag any more. At least two companies offer a line of water-base lacquers through which a multi-color effect can be achieved in one application. Both sliver and dot patterns are available and the paints can be formulated to include any desired combination of colors. Separation of the pigment particles is maintained by a colloidal film.

CERAMIC COATINGS FOR ORDINARY STEEL

A serious attempt to develop ceramic coatings suitable for ordinary carbon steels is reported underway. The object is combined wear and corrosion resistance for inexpensive structural steels.

(Continued on next page)

The Materials Outlook *(continued)*

AIRCRAFT TRENDS

In recent months it has become apparent that aircraft designers are giving more and more attention to the reduction of manufacturing costs. Analysis of materials and processes has resulted in growing application of castings, impact extrusions and the technique of resin bonding. . . . As design temperatures continue to increase, stainless steel honeycomb is being developed to replace aluminum core materials. Adhesives more suitable for the higher temperatures must also be developed. . . . A brazing alloy suitable for temperatures of 1700-1800 F is reported. It would cut jet engine assembly costs.

ALUMINA

Alumina which is claimed to be virtually free of glass-type bond is now being offered commercially. The hard, single-phase, crystalline material is costly but is expected to find chemical, electrical and temperature applications. It is fabricated by powder metallurgy methods.

FLUOROCARBON DISPERSIONS

Fluorocarbon coatings can now be applied to chemical processing equipment made of aluminum and copper. A new dispersing medium is reported to cut baking time at 480 F to about 10 min, making it possible to avoid the softening of such metals that would occur during longer bake periods. The new dispersing medium is also reported to protect the base metal against corrosion where the first or second coats may leave "bare" spots.

FLAME-SPRAYING CERMET COATINGS

Nickel-magnesia cermet coatings 0.001 to 0.20 in. thick are being flame-sprayed on to stainless steel, Inconel and other high-temperature alloys in an attempt to extend the usefulness of ceramic-coated metals beyond 1800 F. (Complete story in this issue).

HIGH-STRENGTH PLASTIC PIPE

High-strength epoxy-glass pipe and pressure vessels are under development. Bursting strengths of more than 100,000 psi have been achieved.

REPLACE STAINLESS?

A new high-temperature alloy claimed to combine light weight with high electrical resistance, good tensile strength and ductility, and good corrosion resistance has been announced. Called "Thermenol", it contains roughly 14 aluminum, 80 iron and 4-5% molybdenum or vanadium. Absence of critical elements is expected to make the new alloy of interest in some applications now utilizing stainless steel.

LESS NICKEL NOW

Steel mill stocks of nickel are reported to be lower now than during the Korean conflict when the metal was closely controlled.

Conference To Spotlight Basic Materials

Engineering materials will be looked at, heard about, and talked over next month when the largest congregation of materials engineers ever assembled gathers for the Second Basic Materials Conference and Exposition. The "Materials Show" will take place May 17 through 20th at the International Amphitheater in Chicago, Illinois.

Basic Materials Conference

Sixteen speakers selected from leading industrial firms and government agencies will lead discussion groups in the Materials Conference. The three day session, chairmanned by T. C. Du Mond, Editor of MATERIALS & METHODS, consists of a broad program covering six major fields of importance to men concerned with materials selection and application. The six divisions are: New Materials; Corrosion; New Metal Forming Processes; Nonmetallics; Joining; and Materials Management.

Conference Features

• The first Conference session to be held on Monday, May 17, will include a paper by Chairman Du Mond, reviewing recent developments in engineering materials.

This look at "Materials of the Future" will be amplified by a talk by Carson Hawk of the Development Department of Aerojet General Corp. on "Rockets and Guided Missiles—How New Materials for Weapons can Help Industry."

• Monday afternoon meetings will cover problems of combatting corrosion. The chairman of this portion of the conference is R. B. Mears, Manager of U. S. Steel's Research and Development Laboratory. Dr. Mears, whose work in metallurgy and corrosion is widely known, will lead discussions on papers dealing with the relationship of corrosion to materials selection.

Tuesday Meetings

Forums scheduled for second day of conference will review new methods of metal forming and the growing field of non-metallic materials.

• The morning meeting on metal forming processes will have as chairman J. H. Jackson, manager of Battelle Memorial Institute's metallurgy department.

Lyle Christensen, casting design consultant for Northrop Aircraft, Inc., will speak on new casting techniques. Dr. H. H. Hausner of the Atomic Energy Div. of Sylvania Electric Products, Inc., will discuss powder metallurgy. J. Walter Gulliksen, General Manager of Worcester Pressed Steel Co. will discuss the relationships and selection considerations for forging, stamping and extruding in metal parts production.

• The afternoon sessions on nonmetallic materials will have as chairman, Charles D. Leedy, Design Engineer of Test Equipment, Bendix Products Div., Bendix Aviation Corp.

The field of plastics will be discussed by Dr. Jesse H. Day, Editor of the Society of Plastics Engineers' *Journal*. Fremont Ruhl will discuss engineering applications of carbon and graphite. Mr. Ruhl is from the United States Graphite Co. Two speakers are scheduled to talk on ceramics: Drs. John H. Koenig and Edward J. Smoke, of Rutgers University, School of Ceramics. The engineering uses of glass will be discussed by W. H. McKnight, Supervisor of Development Engineering, Corning Glass Works. Dr. J. H. Faull, Jr. Consultant to the Office of Naval Research will speak on recent advances in elastomer research and development.

Wednesday Meetings

The third and last day of the conference covers joining and materials management, in morning and afternoon sessions, respectively.

• Charles Leape, of Westinghouse Material Engineering, has accepted the chair of the conference on joining. The adhesive bonding of metals and plastics will be the subject of a paper by George Epstein, Research Engineer, North American Aviation, Inc.

• The windup session of the conference will feature a talk by Dr. M. A. Williamson, Director of Research, Burroughs Corp. Dr. Williamson will analyse the organization and operation of a materials department.

Materials Exposition

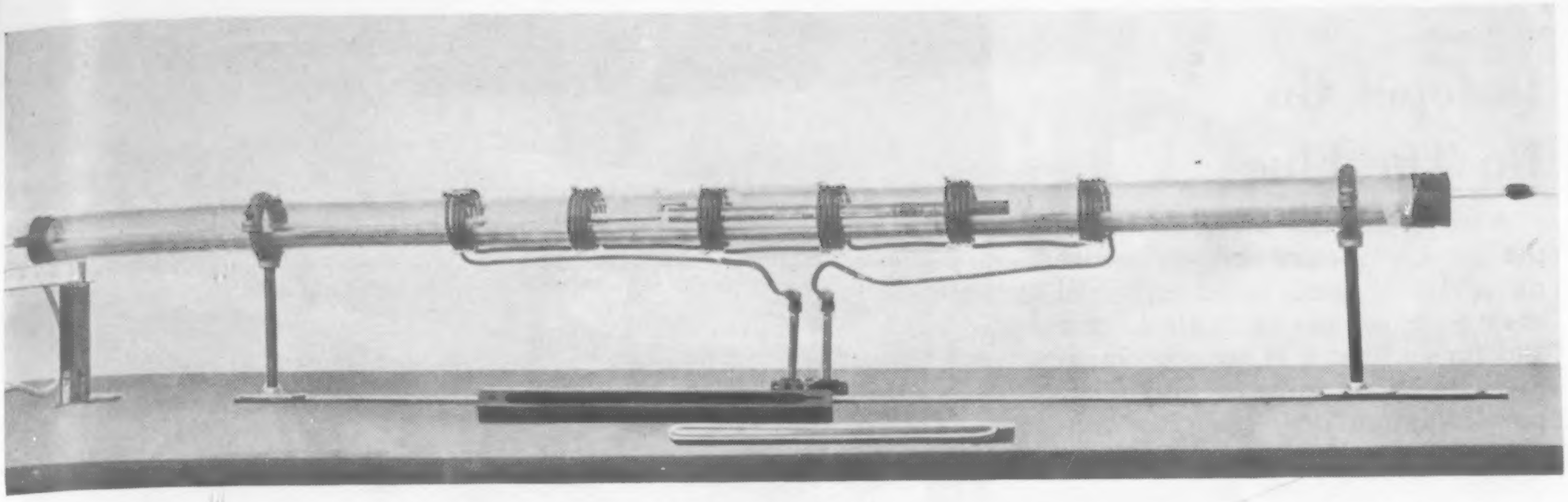
The Second Basic Materials Exposition, which will also be in the International Amphitheater and will run concurrently with the Conference, will offer an opportunity to examine and compare, at one place and time, the hundreds of basic materials available to manufacturers from leading suppliers to industry.

Welding Society Meets in May

Thirty-nine papers on various aspects of welding will be read at the national spring meeting of the American Welding Society, to be held at the Hotel Statler, Buffalo, N. Y., May 4-7. The spring meeting will be held in connection with the second Welding Show, at the Memorial Auditorium, where welding equipment and accessories will be on exhibition.

Major topics to be covered are weldability, inert-arc welding, resistance welding, welding of stainless steel, surfacing and metallizing, resistance welding, pressure vessels and pennstocks, welding of titanium, structural welding, welding processes and equipment, welding of non-ferrous metals, welding of piping and tubing, and a session on welding applications.

Visitors who wish to obtain advance registration cards and hotel reservations should write the American Welding Society, 33 West 39th St., New York 18, N. Y.



Zone melting apparatus of the type used for production of ultra-pure germanium passes ingot through a number of induction coils. Process can be used to purify numerous substances.

Zone Melting Provides Ultra-Pure Materials

Versatile Technique Refines Metals, Compounds, Organic Materials

The "zone melting" technique worked out to produce ultra-pure germanium for transistors and rectifiers is turning out to be useful in a host of other useful applications. And importantly, the process is disarmingly simple, considering that it is capable of purifying almost any number of elements and compounds to a degree never before achieved.

Used in Production

Zone melting, conceived four years ago by W. G. Pfann of Bell Labs, is now in general use producing single crystals of germanium to a purity better than one part in ten billion. This spectacular result is achieved by utilizing the principle that impurities are not equally soluble in the liquid and solid phases of the parent substance. As a matter of fact, the technique has been familiar for generations in such homely applications as producing applejack by allowing a keg of fermented cider to stand out in freezing weather—the water freezes around the outside of the barrel and forces the solute, in this case alcohol, to the center where it can be tapped off through a center tube in a much more concentrated form.

Purifying substances by zone melting is almost as simple. A long narrow ingot of impure material is passed slowly through an induction coil which melts the limited zone of the ingot which is inside the electric field of the coil. As the ingot is run through the coil, the molten zone passes along the ingot, picking up and holding impurities in solution, thus carrying them to the end of the ingot where they solidify in the last volume to freeze. The degree of purification attained by the process depends on the number of passes, the initial impurity level, the difference in solubility of the impurities in the solid and liquid form of the parent material, and on the length of the molten zone. The process is capable of removing impurities which either raise or lower the melting point of the base material, although in the case of higher melting point impurities, the process is somewhat more complex and requires more passes.

Used in Research

While the process is known chiefly for its role in producing germanium for semiconductor applications such as transistors, it is rapidly gaining attention in other fields. Metallurgists have known for a long time that minute trace elements in metals have a tremendous effect on physical characteristics. In order to determine the basic or inherent characteristics of metals, these impurities must be reduced far below the minimum levels that can be detected on such sensitive devices as the mass spectrograph. Zone melting has brought the goal of ultra-purity much closer for many materials, both organic and inorganic.

Experimental zone melting furnace with a single induction heating coil is operated by W. G. Pfann, inventor of the zone melting process. Associate, W. J. H. Scaff, holds a large single crystal of germanium, refined to 99.99999999% purity.

Concentrates Impurities

The process is also important as an analytical tool for isolating trace elements which affect the physical characteristics of materials, yet are present in amounts so small that no ordinary analysis can detect them. Zone melting solves the problem by

(Continued on page 222)

News Digest

Isotopes Go Up The Flue

A series of tests which consumed the largest amount of radioactive material ever used in an industrial testing project has established, once and for all, that it is not economical to charge blast furnaces with finely powdered iron ore. The tests, conducted by the Ford Motor Co. were designed to establish the feasibility of using the fine iron powder obtained from concentration of low grade taconite as a blast furnace charge. In common practice, the powder is briquetted after concentration. Over 76 tons of radioactive iron ore—in powdered and briquetted form,—were used in the tests to trace the flow of iron through the blast furnace process.

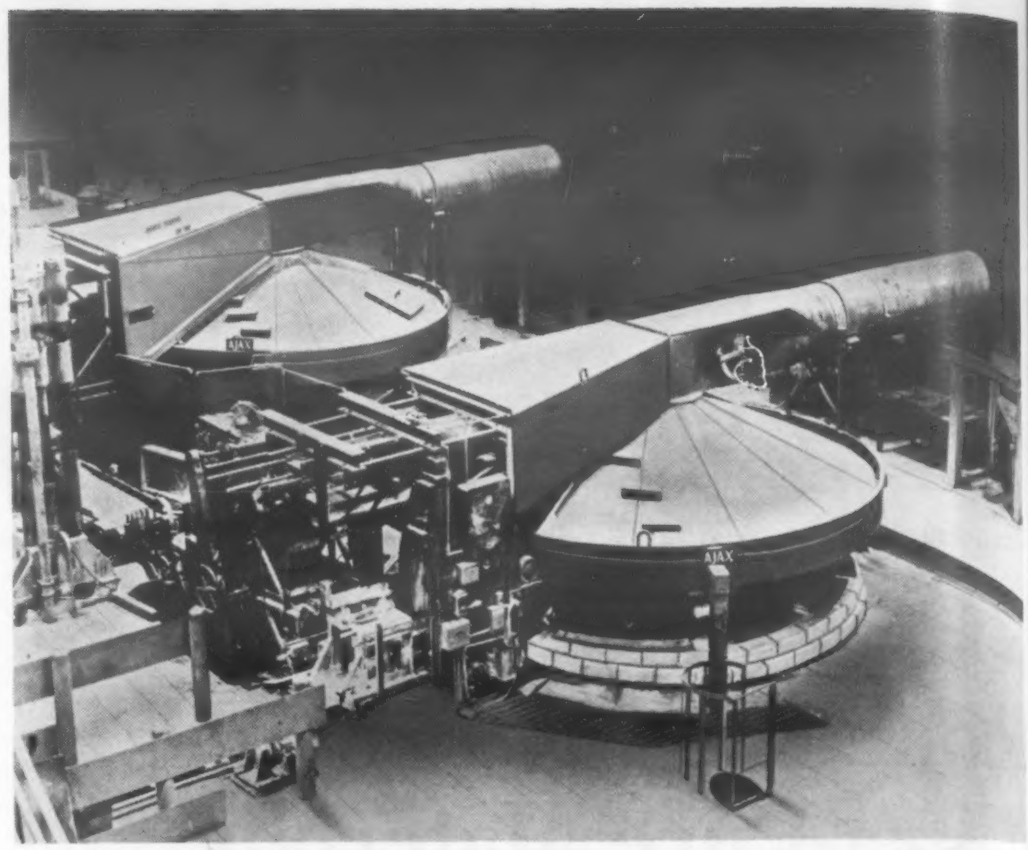
The possibility that a large enough proportion of iron would be retained in the blast furnace to warrant eliminating the briquetting step in ore processing had never been thoroughly established, and the tests were apparently justifiable on that account. The results showed that about 60% of the contained iron was retained in the furnaces charged with powder, but the 40% waste factor was costlier than briquetting.

Old hands in blast furnace operations are probably snorting over the results of the tests, as it has long been assumed that the strong draft of the furnace would blow the powder out the stack long before it had time to be smelted.

Now that things are straightened out, the iron men can stop arguing and start designing a different type of blast furnace to handle powder or think up a cheaper way to briquette the powdered concentrate.

Chlorine Causes Stainless Stains

When phosphoric acid or oxalic acid base cleaners are used to clean stainless steel equipment, the surfaces should first be thoroughly rinsed with water if chlorides are thought to be present. Armco Research Laboratories have learned that a brown-colored etching occurs, which is caused by hydrochloric acid forming when chlorides and phosphoric or oxalic acid are mixed on the stainless steel surface.



Shoots steel billets. Cannon-like salt-bath furnaces heat up to 400 stainless steel billets simultaneously. The billets are fed at 2300 F to hot extrusion presses, where they are hot-extruded into tubing or solid shapes. The salt baths are contained in the circular structure under the barrel-like fume ducts. The billets, which must be heated quickly to prevent grain growth and scaling, are transferred through the bath by means of a carrousel-like mechanism. A 5½-in. dia billet can be heated from room temperature to 2300 F in less than 25 min in the units. *Ajax Electric Co.*

What They Said . . . . .

STANDARDIZATION "There are now 1403 American Standards in actual use. Currently on our books there are 339 projects for standards, under which 107 Committees organized as ASA sectional committees are constantly at work."—*Vice Admiral George F. Hussy, Jr., Feb. 1954.*

DISCOVERY AND USE "The time lag between the acquisition of new scientific knowledge and its application to useful ends is now so short that the rate of our technological progress is largely determined by the amount of our fundamental research effort. Our dependence upon fundamental research, since it yields intangibles, is easily forgotten. Thus it needs the encouragement and support of enlightened groups in schools and colleges as well as in scientific and professional societies." — *Dr. William D. Coolidge, retired Vice President & Director of Research, General Electric Co.*

BETTER THINGS "I firmly believe that we are justified in the assumption that the year 2000 will find our grandchildren looking back to the mid-century with pity—pity because of what they regard as the harsh primitive life we lead today . . . Our scientists and technologists can look back with pride, but they have barely knocked on the outer door of molecular and atomic understanding. If we do not miss our chance, a wonderful world awaits us."—*H. F. Ford, Director of Development, E. I. du Pont de Nemours & Co.*

PLASTIC PIPE "The plastic pipe industry has experienced a phenomenal growth within the last five years. In 1948 . . . . sales approximated $500,000 . . . extruders and materials suppliers conservatively estimate that sales in 1953 approached $30,000,000. Plastic pipe is a practical reality today fully able to stand on its own merits as the most suitable and effective material for numerous applications."—*Bert S. Montell, Society of Plastic Industries.*

Materials BRIEFS

Wanted: The Air Force is looking for a light weight, high strength hose which is resistant to aromatic fuels, yet remains highly flexible at temperatures down to –65 F. Use: in-flight refueling with the probe and drogue technique.

Keeps Cool New protective suits of glass fiber matting and heat reflecting aluminized glass cloth reportedly give up to five times the heat protection of conventional fire fighting garments, weigh only 1/5 as much.

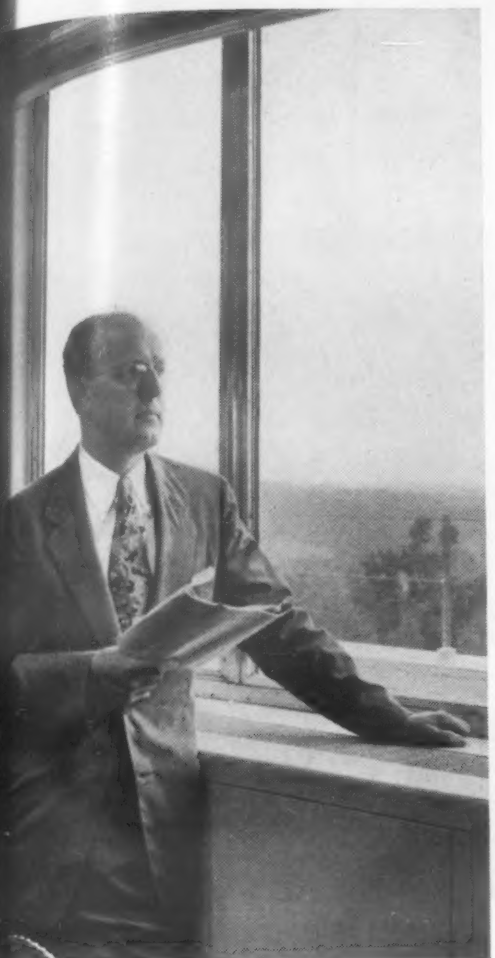
Rockproof Transparent acrylic resin globes for fluorescent street lamps are vandal-proof, will not shatter when hit with a stone. Injection molded globes cover four six-foot lamps.

Big Stretch The largest stretch wrap forming machine now in use can handle sheets as large as 6 by 31 ft, exert stretching tensions over 700,000 lb. Machine is run by a single operator at a control console.

Stain-Free Service A public utility in Philadelphia is building good will by using aluminum wood screws to attach exterior meters to homes of its customers. The aluminum screws prevent unsightly rust streaks from forming on new house paint jobs.

Khaki Scientists Over 13,500 professionally trained engineers and scientists have been assigned to suitable jobs in army technical services after their induction. The army program, now five years old, screens out inductees with college degrees and/or experience in various scientific and engineering fields, assigns them to its scientific billets.

Hot and Cold 105 and 155 mm artillery shells get sixteen hot and cold squeezings. A hot press operation readies the billet, two hot extrusions form it, and thirteen cold drawing passes complete the forming operation. Production rate is 200 per hour.



CHAUNCEY GUY SUITS

Vice President and Director of Research Laboratory, General Electric Co., Schenectady, N. Y.

In the course of developing from an art into a science, metallurgy has accepted contributions from all fields of scientific research. Some of the most recent, and perhaps most promising, developments in metallurgy stem from the esoteric world of the solid state physicists. As knowledge of the inherent character of materials increases through physics research into the realm of super purity and crystal structure, many new materials will be discovered and used. Dr. C. G. Suits is in charge of carrying out a large program of physical research at General Electric. He takes a long range view and speaks confidently.

Men of Materials . . .

their views on development and utilization of engineering materials in industry

In this country, the frontiers imposed by geography are gone, and in a similar way all over the world, geographical frontiers have been disappearing. The frontiers of science and technology are being pushed back too, but there is one remarkable difference; no one can see the limit to the frontiers of science. Each new discovery leads to new mysteries, the solution of which leads to new discoveries, and so on, *ad infinitum.* In nearly every direction in which the scientist and researcher look, the frontiers appear not as boundaries, but as long corridors of many doors, each of which opens upon a long corridor of many doors.

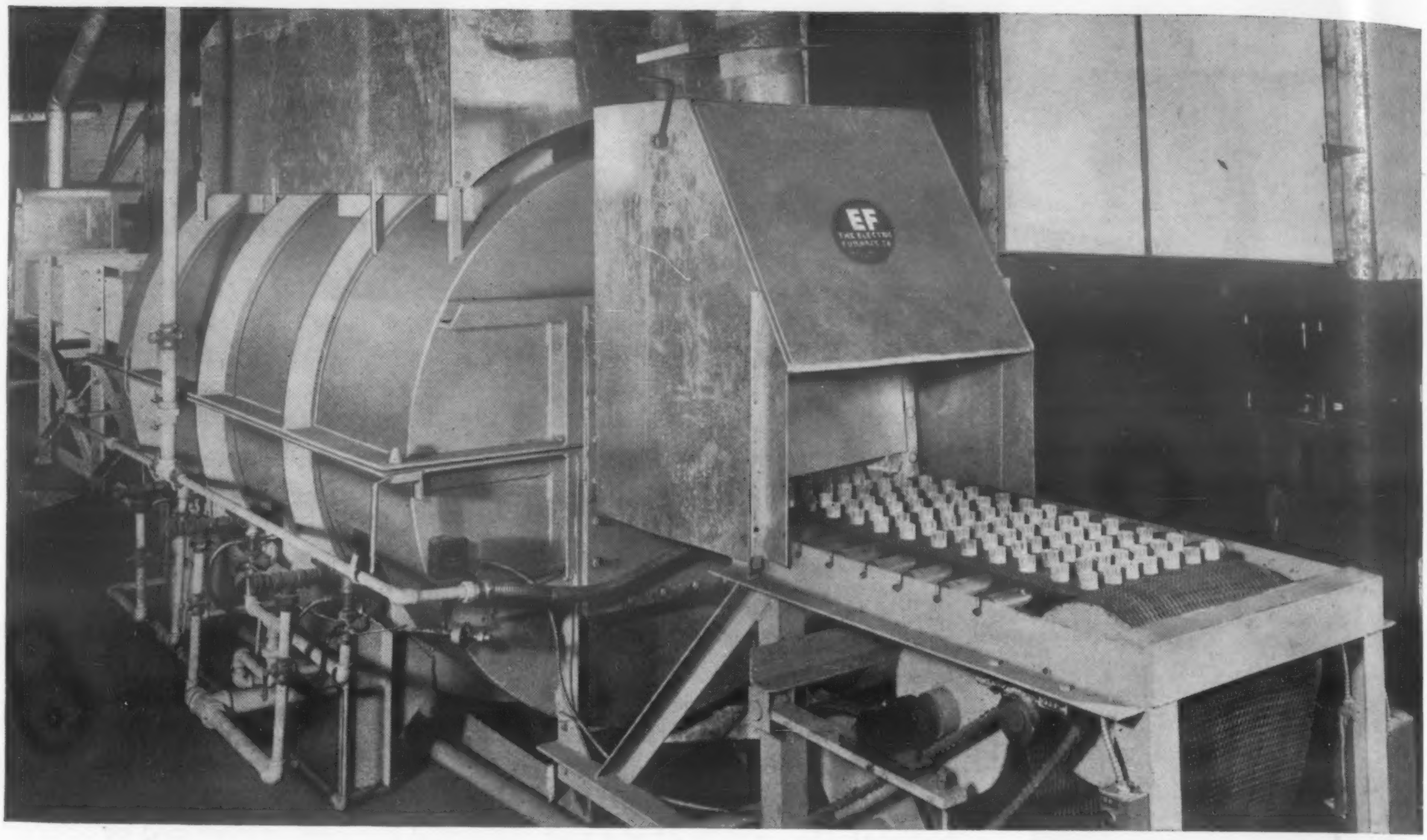
Examples from the field of metallurgy make this clear . . . Only a hundred years ago, the metal practitioner was the blacksmith, but with the growth of the vast industrial complex symbolized by the invention of the steam engine, great developments have come in metals and alloys. Today they literally pace our mechanical progress in a mechanical age. Yet in spite of the astounding progress in adapting the metallic elements of the earth's crust to the physical needs of man, and the impressive science and technology that has built up around this important subject, the whole field is even now on the *threshold* of great new progress based on new fundamental knowledge of metals. Old doors have been unlocked, and exciting new corridors lead in every direction. They will yield new materials and new processes that will effect every technological area in which metals play a part.

. . . One of the very exciting developments in metallurgy has just taken place under the heading of "perfect crystals" . . . We have made in our laboratory some perfect crystals of pure iron . . . that are stronger than any previously known metal or alloy. These tiny crystal wires of iron don't rust at all; the same atomic perfection that gives them strength, prevents oxidation.

No one knows today how to put these perfect crystals to use, and we certainly can't use them at present to support a suspension bridge . . . But, they were only discovered yesterday, and, in time, applied science and technology will find a practical use for this form of metal, for it provides a new dimension for metallurgy.

Beyond all the spectacular progress in specific fields of science and technology, in metals and alloys, in semiconductors, in electronics with all its manifold applications to so many human needs, chemistry, biology and in medicine—beyond all of these is the most striking fact of all. That fact is that applied science in the form of the technological process is an *inexhaustible* source of new wealth.

Somewhere in the study of mathematics one meets for the first time the symbol for infinity—∞—as a concept of something immeasurably great. The storehouse of nature seems to have that infinite dimension.



An EF Gas Fired Cylindrical Muffle Continuous Furnace—one of numerous sizes and types we have built for sintering iron and non-ferrous powder products.

Preview

1954 Metal Powder Show
Tenth Annual MPA Meeting

The 1954 Metal Powder Show and concurrent annual meeting of the Metal Powder Society to be held April 26, 27 and 28 in Chicago at the Drake Hotel will mark the 10th Anniversary of the MPA.

The show will feature the newest developments in metal powders, processing equipment and metal powder products of leading producers in the field. Displays will be located in the Walton Room and in the French Room of the Drake Hotel and will be open from 12:00 noon to 7:00 P.M. on Monday, from 9:00 A.M. to 7:00 P.M. on Tuesday, and from 9:00 A.M. to 3:00 P.M. on Wednesday.

This year, in addition to the three technical sessions scheduled to cover the general subject of powder metallurgy, the meeting will include two separate sessions on electronic cores devoted to subjects of specific interest to those in this specialized field. These will be held on Tuesday and will run simultaneously with the general sessions scheduled for that day.

Two social occasions are planned. A reception including cocktails and buffet supper will be held Tuesday at 5:30 P.M. Luncheon and cocktails at 1:00 P.M. will follow the final technical session on Wednesday. Speaker at the luncheon will be Haldon A. Leedy, vice president and director, Armour Research Foundation.

As in the past, the business sessions of the Association will be conducted on Monday, April 26.

A detailed program of the meeting, including short abstracts of the technical papers and a list of exhibitors for the Show is given below.

Program

All General Sessions will be held in the Grand Ballroom of the Drake Hotel. Electronic Core Session will be held in Room M-18.

Monday, April 26

10:00

Registration opens.

12:00

Exhibit opens in French Room and Walton Room.
Exhibit closes at 7 P.M.

Tuesday, April 27

9:00

Exhibit opens in French Room and Walton Room.
Exhibit closes at 7 P.M.

Morning Session

Chairman: T. L. Robinson, Director, MPA; President Powdercraft Corp.

10:30

FRICTION AND LUBRICATION IN POWDER METALLURGY — *Dr. H. H. Hausner, Manager of Engineering, and Irving Sheinhartz, Senior Engineer, Atomic Energy Division, Sylvania Electric Products, Inc.*

An analysis of friction occurring during the process of compacting metal powders reveals five different types of friction. Methods for determining friction losses are described and the application of these methods for the evaluation of lubricants is discussed. It is shown that a careful selection of the type and amount of lubricant can be made in order to obtain best compacting results.

11:15

LUBRICATION PRACTICES WITH METAL POWDER BEARINGS—*H.D. Krummell, Chief Engineer, Chicago Div., Socony-Vacuum Oil Co., Inc., and J. R. Hicks, Headquarters Staff Engineer, Socony-Vacuum Oil Co., Inc.*

Four phases of the lubrication of sintered metal-powder bearings are discussed: Initial impregnation with oil, re-oiling before installation, lubrication in service, and cleaning and re-oiling used bearings. Lubrication principles, oil characteristics, and the effect of oil additives are considered. Means for re-lubrication in service are illustrated.

Afternoon Session

Chairman: P. E. Weingart, Director, MPA; Manager, Metal Powder Sales, American Metal Co.

2:00

THE NON-DESTRUCTIVE TESTING OF SINTERED BRASS PARTS — *Julian Rossnick, Frankford Arsenal.*

Description of newly developed method for 100% non-destructive testing of sintered brass parts for use in inspecting brass rotors.

2:45

EXPANDING FIELD OF APPLICATION OF METAL POWDER PARTS IN THE AUTOMOTIVE INDUSTRIES—*Joseph Geschelin, Detroit Editor, Automotive Industries.*

One of the largest and perhaps the original user of metal powder parts is the automotive industry. The author describes in detail the nature of the parts being used in today's automobiles as well as those applications unique to powder metallurgy including the newer metallic friction materials and special high density tungsten-nickel-copper parts.

3:30

AIRCRAFT APPLICATIONS FOR POWDER METALLURGY PRODUCTS— *William H. Woodward, Chief, Propulsion Div., National Ad-*

(Continued on next page)

visory Committee for Aeronautics.
The applications of the powder metallurgy in airframe and aircraft engine parts are discussed. The importance of this method of fabrication is stressed in relation to new refractory high temperature materials. Some strength values are listed for an aluminum alloy (SAP) and several cermet compositions.

4:15

POWDER METALLURGY VERSUS OTHER PRECISION FORMING METHODS—*Charles S. Schroeder, Manager-Director, Research and Development Div., Yale & Towne Manufacturing Co.*

Listed here are the various processes of precision forming metal powder parts. Advantages and disadvantages are outlined. The specific process of making metal powder parts is described and details are given showing the characteristics that make the process attractive from the user's standpoint.

Evening Reception

5:30

Reception, including cocktails and buffet supper.

Wednesday, April 28

9:00

Exhibit opens in French Room and Walton Room.
Exhibit closes at 3 P.M.

Morning Session

Chairman: G. A. Roberts, Director, MPA; Vice President, Vanadium-Alloys Steel Co.

10:00

THE MANUFACTURE OF SHEET METALS FROM METAL POWDER—*W. D. Jones, Consulting Metallugist, Powder Metallurgy, Ltd., London, England.*

There is increasing interest in the subject of "powder extraction metallurgy," a title which the author has coined to describe the extraction of metals from their ores developing a metal powder as a finished product. Instead of melting such powders it is more economic to use recently developed methods of directly rolling them to sheet or rod. Rolling processes of this type are described and costs discussed. Methods of manufacture of sheets in heat resisting alloys using a new powder flame spraying gun are also described.

10:45

CARBIDE FLAME-PLATING IN POWDER METALLURGY—*M. A. Teter, Development Engineer, Speedway Laboratories, Linde Air Products Co.*

The flame-plating process is a method of applying tungsten carbide in layers of two to ten thousandths on most any base metal. A 2 to 5 micro inch finish can be obtained by grinding and lapping. By flame-plating, it is now possible to combine a hard wear resistant coating with desirable base metal characteristics, such as toughness, conductivity, low weight, low inertia, coefficient of expansion.

11:30

SEMI-FORMED DRAWING STOCK BY POWDER METALLURGY — *Robert Steinitz, Research Supervisor, American Electro Metal Corp. and Frank Zaleski, Metallurgist, Frankford Arsenal.*

The iron powder for the production of cartridge cases is selected considering the required properties in the sintered piece. Preforms in the shape of cups are molded, sintered, coined and resintered to supply pieces which are suitable for drawing. Drawing experiments are performed at Frankford Arsenal. Raw Material, production conditions and equipment necessary will be discussed, as well as the properties of the finished part.

Luncheon

1:00

Luncheon. Speaker: Haldon A. Leedy, Vice President and Director, Armour Research Foundation.

Electronic Core Session
Tuesday, April 27

Chairman: W. E. Cairnes, Director, MPA; President, Radio Cores, Inc.

Morning Session

METHOD OF DETERMINING TEMPERATURE OF COEFFICIENT OF ELECTRONIC CORE MATERIALS—*Richard H. Rodrian.*

SOME ELECTRONIC APPLICATIONS OF IRON POWDER CORES—*David M. Hodgin.*

Afternoon Session

THE APPLICATION OF METAL POWDER ASSOCIATION CORE STANDARDS AND DATA SHEETS—*Lester M. Becker.*

THREADED IRON CORES: USES AND APPLICATIONS—*Panel Moderator: Richard D. Ponemon.*

Panel: L. D. Andrews, Hugh T. Blair, William W. Bosse, F. Edwards, R. Fetzner, Sidney Lowenberg, Jay Sebesky.

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—One Point of View

Tell The World About Your Technical Progress

There is considerable reason to ponder over the opposing points of view to be found among many of our large companies in their policies regarding the release of technical information. Some companies encourage their engineers to write and publish papers and articles dealing with developments they have worked on. In fact, these companies spend rather large sums of money to assist engineers in such writing and even help in finding publishers for their work. Other companies take just the opposite position. No one is permitted to publicize anything that goes on within their organizations, unless it might be that Joe Doakes has been appointed district sales manager in Waukesha.

There doesn't seem to be a good answer for the latter attitude other than selfishness. On the other hand, there are several reasons why a company should share its knowledge. Here are some:

1. It is important that there be a constant interchange of ideas among technical people in order that all might progress. It is possible that competitors might benefit from reading about what a progressive company is doing, but there will be a lag of many months. Too, reading about what you do does not mean that a rival company is going to copy your method immediately. Thus the disadvantage is minor, if indeed, it is a disadvantage. On the plus side, release of information is likely to stimulate others to tell what they know.

2. Most engineers get little recognition for their work outside of their own companies, and sometimes not even there. An opportunity to have their work publicized will permit engineers to attain the respect and recognition they merit. Such respect can be important in company human relations.

3. Company reputation built on sound engineering developments is a valuable sales asset whether the product be of an industrial type or strictly for the consumer market. It is interesting to note that the two automobile manufacturers that dominate the field are most free in divulging technical information. And, aircraft companies who never hope to sell to anyone but government are eager to build their reputations through engineering articles in technical publications.

There are other advantages which could be cited, but the three listed are sufficiently important to merit consideration. Too many companies seem to feel that the release of an elaborate financial report constitutes a public relations program. Technical public relations might not be spectacular, but it is sound.

J.C. Du Mond

Centrifugal Compacting—A New Method

Offers economies and uniform density in large parts made with heavy powders . . . Is being used to form tungsten carbide bullet cores.

by **ROBERT C. LINDBERG,** Chief Development Engineer, Firth Sterling Inc.

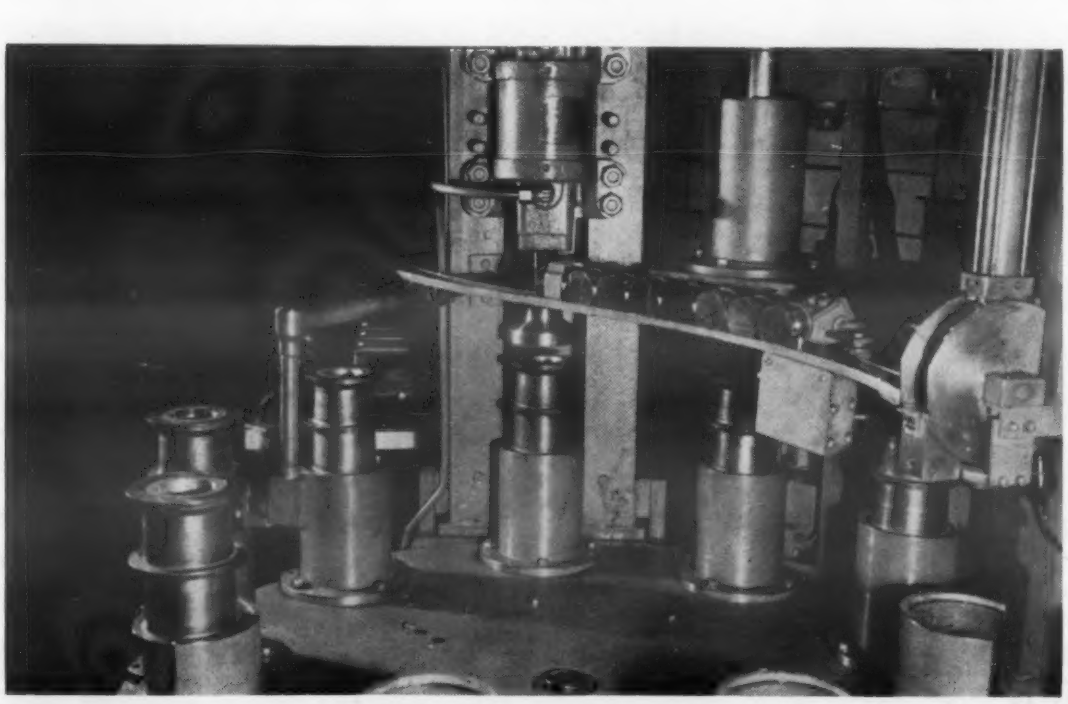
● A MAJOR LIMITATION of powder metallurgy has been the difficulty of making large parts with uniform properties throughout. The density of a deep compact formed on an automatic press is markedly higher at the ram face than at the opposite face. Compacts made by hydrostatic pressing are more uniform but must be shaped or machined with resultant waste of powder and high labor cost. Hot pressing produces a shaped, uniform compact but requires a separate, costly graphite mold for each part made.

Many of these drawbacks seem to have been overcome in a new method known as centrifugal compacting. Now being used successfully in the production of 4-lb tungsten carbide bullet cores, the new technique seems to offer promise for many similar applications.

In centrifugal compacting the charged molds are whirled around in a circle at speeds approaching 300 mph. Centrifugal force pulls the powder toward the perimeter of the circle. The theory is that, since centrifugal force acts directly on each individual grain of powder, the inter-particle friction that limits the effectiveness of other compacting techniques is at least partially overcome and the grains are freer to flow in directions angular to the lines of force.

The pressures achieved in centrifugal compacting do not approach the pressures normally used in pressing tungsten carbide. Centrifugal compacting involves pressures on the order of 2 tons per sq in., whereas normal compacting pressures for tungsten carbide range from 12 to 15 tons per sq in. Although the surface of a green compact made on the centrifuge seems to be equivalent to that made by a press, microexaminiation proves the pressed compact smoother. However, there is no significant difference in surface finish between compacts made by the two methods after sintering.

Since the amount of shrinkage during sintering depends inversely on the density of the green compact, compacts made on the centrifuge shrink considerably more than compacts made by a press, and molds must be designed accordingly. The size of the final sintered piece can be closely controlled by adjusting the speed of the centrifuge. In order to compensate for the smaller force exerted on the powder travelling the inner or smaller circles, a free disk of carefully calculated weight is placed at the inner end of the mold to add its own radial force to that of the powder.



ROTARY LOADING TABLE *where bullet core molds are charged automatically.*

THE CENTRIFUGE *is shown here with one of the four mold carriers raised and ready to receive two charged bullet core molds.*

Limitations

Final sintered densities and strengths achieved in parts made by centrifugal compacting appear to be equivalent to those achieved by other methods. Despite the advantages of greater uniformity and lower cost, however, the method has important limitations.

First, it is not suitable where extreme pressures perpendicular to the

for Producing Metal Powder Parts

lines of radial force are needed. This would seem to eliminate parts with abrupt changes in cross-section. The simple shape of a bullet core is almost an ideal application. Further work will be needed to determine how much more complex a cross-section can be handled successfully.

Second, the centrifugal technique does not seem to be adapted to parts having extremely small cross-section, i.e., on the order of $\frac{1}{4}$ in. Such parts are more porous after sintering than those made by other compacting methods. Porosity decreases as cross-section increases; this is probably due to the diminishing effect of mold wall friction as the proportion of wall surface to volume of powder decreases.

It is possible that centrifugal compacting can be extended to materials other than the heavy carbides. It is important to realize, however, that the effectiveness of the method depends on the density of the powder. With rotational radius and speed constant, the compacting force exerted is directly proportional to powder density. Therefore, the method could be expected to prove less effective with the lighter metallic powders.

Nor is it likely that the size of parts to be centrifugally compacted can be increased appreciably. The size of the rotor, as well as its speed, is limited by safety considerations to a range in which the operating stresses at the rim do not exceed the strength of the rotor material.

Process Developed in Sweden

Although the centrifugal compacting process described in this article was developed by Firth Sterling engineers, a later investigation showed that the principle had already been patented by Sandvik Steel Works Co. of Sweden. An agreement was reached with that company before the centrifuge was built. The machine now being used in production was designed and constructed in conjunction with Sharples Corp., a company with wide experience in the manufacture of centrifuges.

How Cores Are Made

The mold for the bullet core is made of aluminum in four sections which are closely machined. The cavity is made larger than the core to allow for shrinkage that occurs during sintering. The outside surfaces of the aluminum mold sections have a continuous taper to allow subsequent press fitting of the segments into a steel cylinder with matching internal taper. The mold segments are assembled in the steel backing cylinder and the assembly is placed in one of the nine positioning tubes on a rotary table. With the table indexing automatically every 40 sec, the mold assembly passes through three loading stations. At the first station a hydraulic ram firmly presses the mold segments into the steel cylinder. At the second station a pre-weighed charge of powder is poured into the mold and tamped. At the third station a weighted disk or plunger is placed in the mold and lightly pressed into position. In addition to compensating for the lower centrifugal force at the back of the mold, the plunger squares off the back of the core and thus avoids the need for subsequent shaping.

The centrifugal compacting machine has a rotor 44 in. in dia and 10 in. high made from a solid cylinder of aluminum. The rotor contains four machined cavities, each containing a mold carrier capable of holding two bullet core molds; thus, eight cores can be pressed simultaneously. Charged molds are inserted in the mold carriers which are then lowered into the rotor cavities. The mold carriers operate on hydraulic lifts to ease loading and unloading of the rotor.

The aluminum rotor is mounted on a $2\frac{1}{2}$-in. dia steel shaft supported by a bearing housing. The whole assembly rests on a steel tripod, each leg being spring-suspended. The rotor is belt-driven from a 40-hp motor which uses direct current supplied by a motor generator set. An elaborate power control panel makes it possible to adjust rotor speed, time needed to attain speed, time at speed and braking time. The charged rotor is started and gradually raised to the selected compacting speed. It is held there until automatically engaged by the brake and gradually brought to a stop. The complete cycle requires about 6 min. Rotational speeds range from 1800 to 2600 rpm, so the outer rim of the rotor may attain a speed up to 300 mph. Without braking, about 30 min or more would be needed to stop the rotor.

After compacting, each mold is removed from the rotor and placed in a stripping fixture. A horizontal hydraulic ram presses the four aluminum mold segments containing the compact from the tapered steel cylinder. The segments are then lifted from the compact, and the bullet core is ready to be sintered.

Safety Precautions

It is clear that the large diameter of the rotor and the high rotational speeds make centrifugal compacting a potentially hazardous method. However, construction of the machine was well-engineered and extreme care is exercised by the operators. In addition, elaborate safety devices have been adopted. A ring of steel surrounds the rotor, and the entire operation is segregated by concrete block partitions. A sliding steel door provides entrance through the concrete wall. When the door is open the rotor will not start, but it opens automatically when the rotor stops. A thermocouple in the bearing housing reacts to any undue rise in bearing temperature by cutting off the power and engaging the brake. The rotor will not start unless the mist oiler which lubricates the bearings is in operation. Another device limits vibration to a previously selected frequency; if this frequency is exceeded the rotor begins to decelerate. All precautions, as well as the proper sequence of operations, are described in a manual supplied to the operators who are thoroughly trained beforehand.

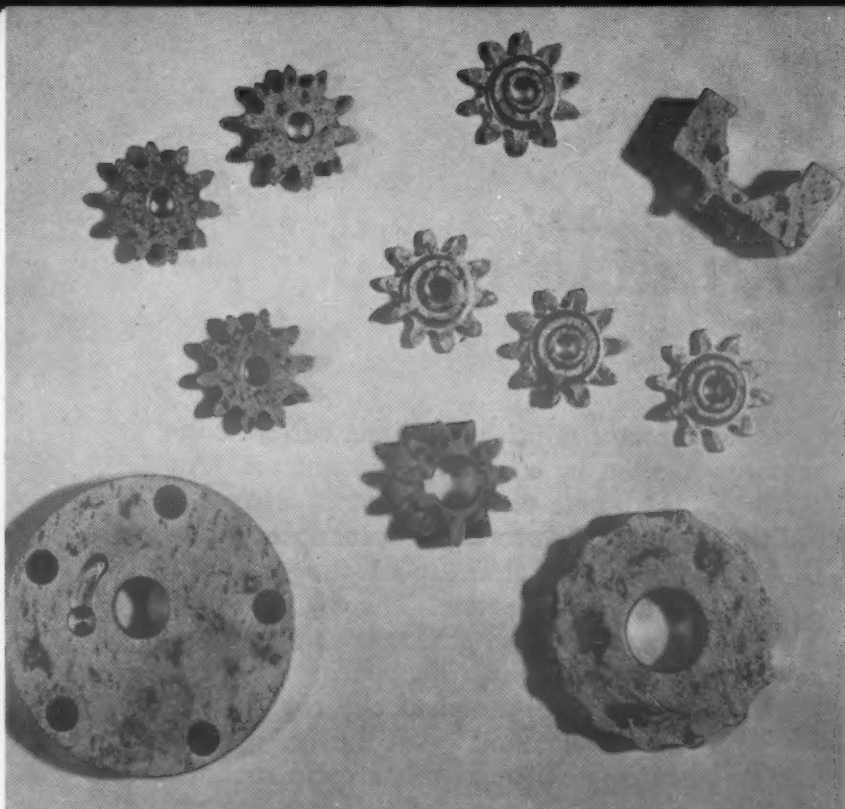


Fig 1—Sintered iron adding machine parts, cadmium plated without impregnation, show pitting after 10 days atmospheric exposure.

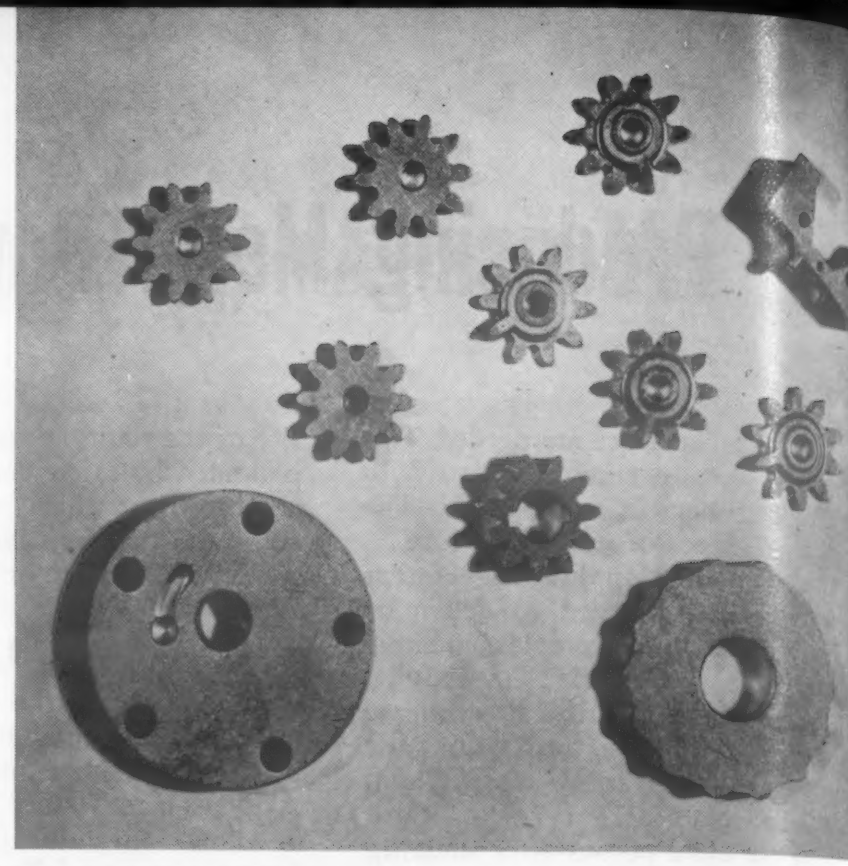


Fig 2—Sintered iron adding machine parts, plastics-impregnated before cadmium plating, show no corrosion after 5 months exposure to the atmosphere.

Infiltration Improves Properties of Metal Powder Parts

by JOHN L. EVERHART, Associate Editor, Materials & Methods

Infiltration of metal powder skeletons is rapidly growing as a method of producing strong metal powder parts.

● THE DENSITY OBTAINED in forming metal powder parts at a reasonable pressure, ranges from about 65 to 85% of theoretical density. There are several methods of obtaining higher densities. These include compacting under greatly increased pressures, forging, hot pressing, coining and infiltration. All of these methods excepting infiltration increase the density by closing the pores. In infiltration, however, advantage is taken of the porosity to introduce another material which fills the pores and increases the density by this means.

The mechanical properties of a metal powder compact are closely related to the relative density because pores act as internal notches. By the elimination of porosity, considerable improvement in strength and ductility can usually be obtained. Thus, in the formation of iron-copper compacts, pressures of about 25 tons per sq in. can be used to form the iron skeleton. This skeleton after infiltration with copper has been found to be at least as strong as a medium carbon steel compact pressed at 60 tons per sq in., sintered, repressed and resintered.

For the successful infiltration of porous compacts with metals, certain conditions must be met if optimum results are to be obtained. The melting points of the two metals should be as far apart as possible, limited solubility is advantageous, and intermediate phases should be limited as they can hinder the progress of infiltration. In the infiltration operation, the temperature should be maintained as close to the melting point of the infiltrant as possible to prevent washing, the time should be short to minimize alloying, and oxide skins must be avoided.

The nature and degree of improvement obtained by infiltration depends to a certain extent on the characteristics of the skeleton and the infiltrant. There are a number of possible relations between these materials, 1) if no solubility and no wetting occurs, the product has a duplex structure and the properties are dependent upon the relative quantities of the two materials, 2) if wetting occurs but there is no mutual solubility, the structure is again duplex and the properties are not changed greatly and 3) if wetting and solubility exist, the product is capable of developing good mechanical properties which, in systems having limited solubility, can often be improved by precipitation hardening heat treatments.

No Wetting or Solubility

This is the case when a porous compact of iron, for example, is infiltrated with a plastics material. With an infiltrant of this type there is no significant improvement in me-

Applications for Infiltration (After Stern)

Application	Useful Temp Range	Skeleton Composition	Infiltrant
Electrical Contacts	Room	Tungsten, tungsten carbide, molybdenum, molybdenum carbide	Copper, silver
Counterweights, radioactive shielding (heavy metal)	Room	Tungsten	Copper-nickel
Brushes	Room	Graphite	Copper and copper-base alloys
Bearings	Room	Graphite, Iron, steel	Copper and copper-base alloys, Lead
Jet engine compressor blades	300–700 F	Iron, steel	Copper-base alloys
Structural parts	Room	Iron, steel	Copper-base alloys
Nozzle vanes, jet engine buckets, valve seats and guides	1100–1800 F	Titanium carbide, titanium-molybdenum carbide	Nickel-chromium, cobalt-chromium, Stellite, Inconel, stainless steels

chanical properties of the compact even though the pores are filled. The practical value of impregnation with a plastics material is the elimination of internal pores in which corrosion can occur. Another advantage is the improvement of pressure tightness.

Thus in plating, pores are disadvantageous because the cleaning solution can penetrate them and may react either with the metal or with trapped gases to produce salts having a greater volume than the pores. This material exudes, interferes with plating and produces an unsightly surface appearance.

To eliminate porosity, compacts are impregnated commercially with a thermo-setting polyester-styrene copolymer using a combination pressure-vacuum process. After polymerization, the plastic is non-corrosive to the metal, inert to most chemicals and can withstand temperatures ranging from —75 to 400 F. The impregnant makes the compacts pressure tight for pressures up to at least 5000 psi. Impregnated and polymerized compacts can be plated as readily as the same metal in wrought form.

Self-lubricating bearings have been produced by impregnating a porous metal shell with polytetrafluoroethylene. This plastic has the advantage of a low co-efficient of friction but has poor thermal conductivity and dimensional stability. These disadvantages are overcome by impregnation.

The infiltration of oxides such as alumina with liquid metals to form cermets is another example of a system in which neither wetting nor solubility occurs.

Wetting but No Solubility

A system of this type probably represents the first application of infiltration to powder metallurgy. In the electrical contact field, composite contacts have been produced for many years from tungsten or molybdenum compacts infiltrated with copper or silver.

Both tungsten and molybdenum are excellent contact materials because they are resistant to mechanical wear, to losses due to arcing, and to metal-to-metal sticking under contact pressure. However, the resistance to sticking is the result of the formation of oxide films, and the high resistance of the films limits the use of pure tungsten or molybdenum to high voltage service. To use the excellent contact properties of these metals at lower voltages, a combination with high conductivity metals such as silver or copper is necessary. Since these refractory and conductive metals do not form alloys, combinations are made by powder metallurgy processes.

The process consists of pressing and sintering the tungsten or molybdenum compact into a porous skeleton which can be either the final form or a blank, and impregnating with either silver or copper. Since there is no solubility, dimensional accuracy can be maintained. Generally the impregnant ranges from 30 to 60% of the composite material. After impregnation, the composite can be worked into final form by forging, extruding or other methods, if desired.

Another application of this kind is the production of steel-backed bearings. These bearings have been produced for some years by sintering a porous layer usually consisting of about 50% copper and 50% nickel on a steel sheet. The copper brazes the nickel to the steel and a strongly adhering skeleton results. After sintering, the pores are impregnated with lead or a high-lead bearing alloy. Suggestions have been made that suitable bearing alloys can be obtained by impregnating iron skeletons with lead or lead-tin alloys. Among other suggestions have been the infiltration of iron compacts with lead or tin to increase the density, improve the corrosion resistance and increase the ease of plating.

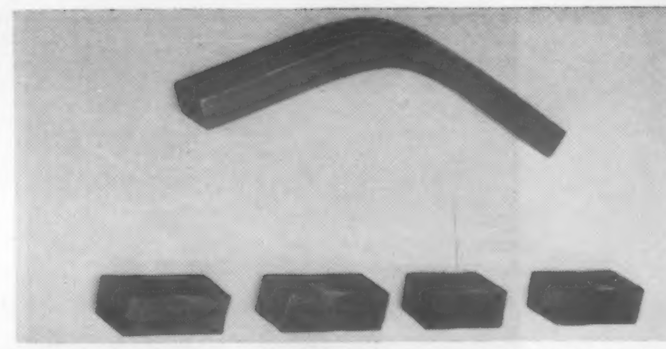


Fig 6—Comparison of infiltrated and cemented (sintered) titanium carbide. Bottom—Nickel cemented titanium carbide, 63,000 psi modulus of rupture and 1/2-deg bend angle at 1800 F. Top—Nickel alloy infiltrated titanium carbide, 73,000 psi modulus of rupture and 48-deg bend angle at 1800 F.

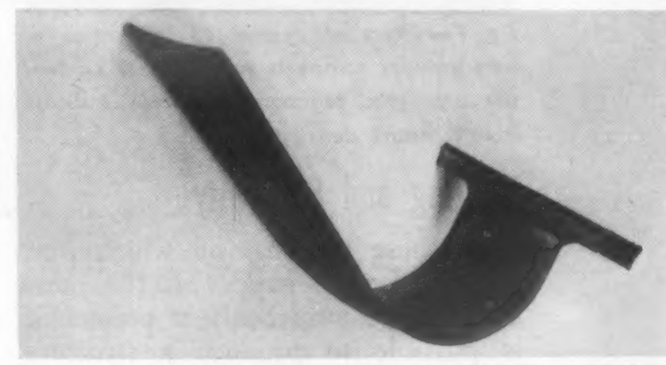


Fig 3—Typical jet engine compressor blades made by infiltrating iron skeletons with copper.

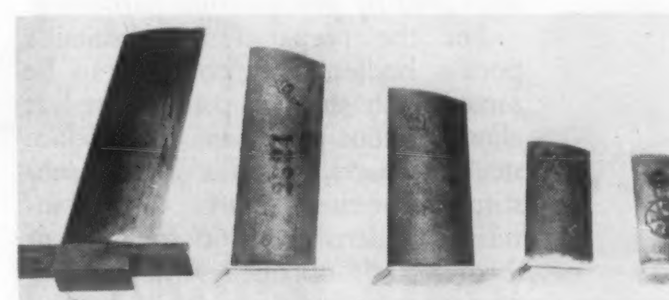


Fig 5—Cold bend test shows ductility of jet engine compressor blade of iron infiltrated with copper.

Impregnation of austenitic stainless steel skeletons with silver has also been proposed. The silver does not alloy with the steel but strengths of 40,000 to 50,000 psi and elongations of 10 to 12% have been obtained in these composite materials.

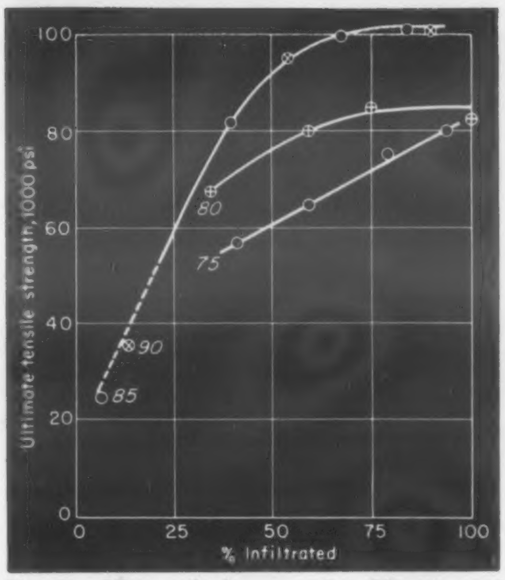


Fig 7—Effect of degree of infiltration of iron powder compacts with coppor on tensile strength. Figures on curves indicate iron compact density.

Wetting and Solubility

In these systems, of which iron infiltrated with copper is the most important commercially at present, it is possible to produce a structure having excellent mechanical properties which in some cases can be improved by precipitation hardening.

For the preparation of suitable porous bodies, iron powder can be mixed with stearates and pressed at about 25 tons per sq in. To produce steel compacts, graphite can be substituted for the stearates. Upon sintering, a density of 60 to 85% of theoretical is obtained and a system of interconnected pores is formed which is suited for impregnation.

About 8% iron is soluble in copper and impregnation with pure copper produces rough surfaces of poor appearance and some rounding of the edges due to alloying. However, this effect can be overcome to a large extent by using a copper alloy as the liquid medium. At present, iron skeletons are often impregnated with a copper-iron or copper-iron-manganese alloy and the residual porosity is reduced to less than 4% by this means. Copper impregnated iron has a tensile strength in the range 50,000 to 60,000 and elongations of 14 to 30% before precipitation hardening. After precipitation hardening, the strength may be above 100,000 psi with elongations up to 8%. These results are superior to those obtainable by pressing and sintering mixtures of powder of the same composition.

One of the outstanding applications for iron impregnated with copper is the stator blade for jet engine compressors. Well over 10,000,000 of these blades have been produced.

These blades are produced by molding iron powder into a preform, sintering and coining to the exact dimensions required which include a thin trailing edge and a thicker leading edge. The porous blade is infiltrated with approximately 20% of a copper alloy to practically theoretical density and given a precipitation hardening heat treatment. The resulting blade has a specified minimum tensile strength of 90,000 psi and an elongation of 8%. Further developments in this blade in the direction of obtaining increased strength are in progress and tensile strengths of 150,000 psi with elongations of 5% have been reached.

Among the advantages claimed for the infiltrated blades are elimination of heavy forging equipment, extended die life, lower scrap loss and the use of less highly skilled labor. The composite blades can be nickel or chromium plated, soft soldered or brazed.

Iron parts infiltrated with copper are used also for structural parts such as washing machine gears.

Stainless steels have been used as the skeleton material with copper and various copper alloys as impregnants. The infiltration of a stainless steel with silver has been mentioned and similar work has been done on a stainless steel-copper combination.

In this development copper was infiltrated into austenitic stainless steel skeletons. By sintering the compact before infiltration, strengths of 100,000 psi and elongations of 5 to 6% were obtained. Since these materials are soluble to some extent, the strength values are considerably better than those obtained with the stainless steel-silver combination.

Among other developments is the infiltration of refractory carbides with various high temperature alloys to develop new high temperature materials. Porous titanium carbide compacts infiltrated with high temperature nickle or cobalt base alloys have shown excellent strength combined with notable ductility and impact resistance at temperatures up to 1800 F. They have also exhibited satisfactory resistance to oxidation up to this temperature. Impregnated titanium carbide parts of this type have had transverse rupture strengths up to 300,000 psi at room temperature and up to 150,000 psi at 1800 F. At room temperature, similar parts have had impact strengths of 10 ft-lb as determined on an unnotched Izod bar which compares with 3 to 3.5 ft-lb for cemented titanium carbide of the same composition.

In 100 hr stress rupture tests, infiltrated titanium carbide parts have had strengths of 38,000 psi at 1600 F and 16,000 psi at 1800 F. These contrast with 21,000 psi at 1600 F and 11,300 psi at 1800 F for the best cast superalloy now in use in jet engine components.

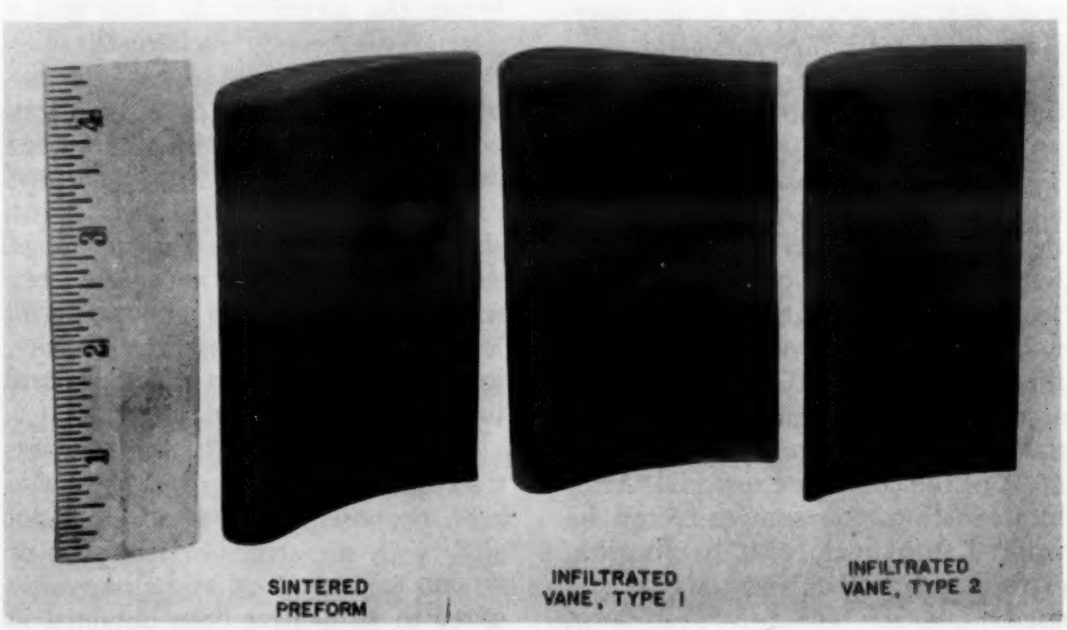


Fig 4—Jet blade nozzle vanes made from infiltrated titanium carbide.

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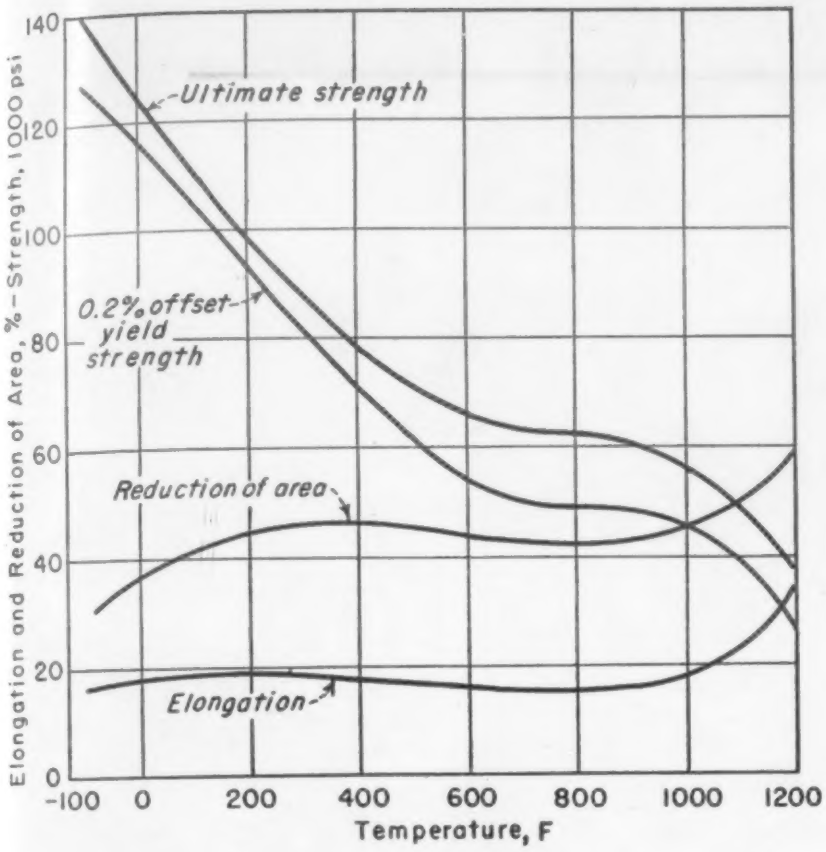
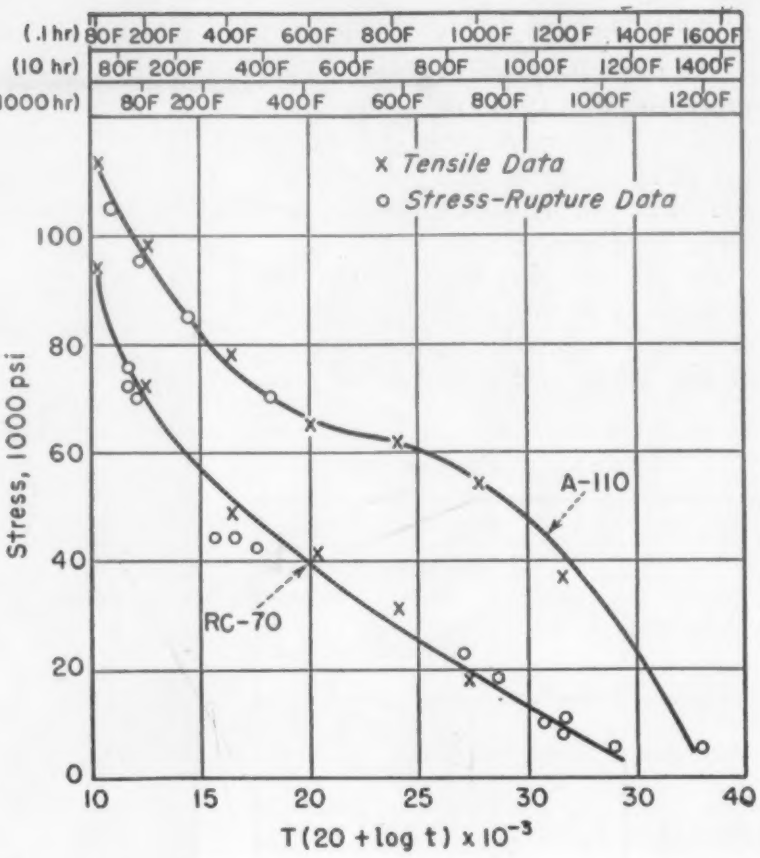


Tensile properties vs. temperature of A-110AT titanium annealed sheet.



Rupture curves of A-110AT and RC-70 titanium annealed sheet.

by G. E. HUTCHINSON, D. W. KAUFMANN, and R. C. DURSTEIN, Rem-Cru Titanium, Inc.

New Weldable Titanium Alloy

• Is first commercial alpha type titanium alloy

• Has high hot strength and ductility

• COMMERCIAL PURE TITANIUM is readily weldable, but the available titanium alloys have given brittle welds. Recently, a weldable titanium alloy, Rem-Cru A-110AT, was introduced which combines high hot strength and good ductility with its ability to be welded.

Of the three basic types of titanium alloys—alpha, beta, and combined alpha-beta—only the last mentioned type has been produced commercially. Since the alpha alloys promised good weldability, high hot strength and toughness, there has been considerable effort in the industry to develop a suitable alloy of this type. The promise of high toughness, hot strength and weldability has been realized in Rem-Cru A-110AT.

Composition

The nominal composition of A-110AT is 5% Al-2½% Sn, with a total interstitial content of about 0.2%. Aluminum has proven to be an excellent alpha alloying addition because it: 1) promotes good hot strength, 2) preserves weld ductility, 3) raises the beta transus, thus increasing oxidation resistance and allowing higher hot working temperatures, 4) is low in density, 5) is low in cost, 6) is strategically available.

Titanium-aluminum alloys, however, cannot be readily fabricated by production practices above about 6% aluminum content. Tin, when added at an aluminum alloy level where satisfactory fabrication is obtained, improves the strength without affecting fabrication characteristics to any great degree. In addition, tin possesses the following advantages: 1) high alpha solubility (approximately 18%), 2) low vapor pressure, therefore alloying with titanium without appreciable evaporation, 3) preserves weldability, and due to above mentioned low vapor pressure, will not evaporate during welding, 4) increases hot strength slightly, and 5) ample tin will be available even during an emergency.

Since tin is substantially heavier than titanium, its effect on the density of titanium alloy might be considered a disadvantage. This has not proven to be the case for A-110AT. The addition of 2½% Sn to a Ti-5% Al alloy raises the density from 4.42g/cc to only 4.44g/cc, still less than that for pure titanium (4.52-g/cc).

Properties

Tensile Properties—The tensile properties of 1/10 to 1/8-in. sheet produced recently average 110,000 psi yield strength, 116,000 psi tensile strength, 18% elongation, and 40% reduction of area.

As shown in the figure, the strength is 15,000-20,000 psi higher at —80 F with only slightly lowering of elongation and reduction of area.

Endurance Properties

Specimen	Notch Severity	Endurance Limit R=+0.25 10^7 cycles	Strength Reduction Factor
Unnotched	—	98,000	—
Notched	$K_t = 2.0$	63,000	1.55
Notched	$K_t = 4.0$	36,000	2.70

$$K_t = \frac{\textit{unnotched endurance limit}}{\textit{notched endurance limit at same "R" and life}}$$

Inert-gas-shielded metal arc welding shown here being used on aluminum also produces sound welds in the new titanium alloy.

Comparative Properties of A-110 AT and Other Materials

Material	Tensile Str, Psi	Yield Str, Psi	Elong, %	Unnotched Fatigue Strength at R = + 0.25 10^7 cycles
A-110 AT	116,400	110,400	18.5	98,000
SAE 4130	117,000	98,500	14.3	97,000
75 S-T 6	82,500	76,000	11.4	46,000
24 S-T 3	73,000	54,000	18.2	47,000

Properties of Welded Joints

Material	Welding Method	Tensile Tests				Bend Tests		
		Yield Str 0.2% Offset, Psi	Tensile Str, Psi	Elong, % 2 in.	Location of break	Angle of failure, deg	Elong, % 2 in.	Location of break
RC-70	Aircomatic	81,000	96,000	19.5	in base metal	180	20	none
A-110 AT	Aircomatic	108,000	117,000	7	in weld	85, 180[1]	18	1 in. weld
RC-70	Heliweld	81,000	96,000	23	in base metal	180	20	none
A-110 AT	Heliweld	100,000	117,000	15	in base metal	50 to 69	15	in weld

NOTES: [1] *Tests made on 0.100 in. sheet one sample at 85 deg, 2 to 180 deg Bending jig: 1/4 in. radius mandrel, 1/4 in. die.*

With rising temperatures, the strength drops off steadily to about 55,000 psi yield strength at 600 F, and to 25,000 psi at 1200 F. Elongation and reduction of area remain fairly constant up to 1000 F, after which both increase rapidly.

Tensile properties of bars and forgings are similar to those of sheet. The strength levels are on the high side of the normal spread between heats. Strengths of 5/8-in. rounds are equal to those of 6-in. rounds although ductilities are higher.

Bend Ductility—The minimum bend radius of A-110AT sheet at room temperature runs between 2.5T and 3.5T (through 105 deg on a V-block). At —80 F the value is as good and in many cases better than at room temperature. Preliminary data indicate no improvement in bend ductility at elevated temperatures up to 900 F. Sheet has proven to be isotropic in both tensile and bend tests.

Fatigue Properties—Fatigue tests have been run on A-110AT sheet from one representative heat. These tension-tension fatigue tests were run with an axial load of S min=0.25 S max and with unnotched, notched (K_t=2.0) and notched (K_t=4.0) specimens.

The average endurance limits and strength-reduction factors are tabu-

The high hot strength of the new aluminum-tin-titanium alloy requires that hot forming be done at temperatures higher than other titanium alloys.

lated. A-110AT sheet has good tension-tension fatigue properties, the unnotched fatigue strength being 85% of the ultimate strength.

A table shows that in both unnotched and notched tension-tension fatigue tests run recently, the A-110AT sheet is equal or superior to SAE-4130 steel and is much better than 75S-T6 and 24S-T3 aluminum alloys.

Notch Sensitivity—Using standard Charpy V-notch specimens, it has been found that normal energies absorbed are 20 ft lbs at room temperature and 16 ft lbs at —40F for ⅝-in. forged plate. The lowest values are obtained when the notch is perpendicular to the forging plane.

Stress Rupture and Creep—Master rupture curve for A-110AT plotted from actual tensile and stress-rupture data are given in a figure. The curve for commercially pure grade RC-70 is shown for comparison. The attractive high temperature properties of the new alloy are apparent.

Insufficient data are available at present to permit publishing creep data. Tests are currently underway, however, and the results should be available in the near future.

Corrosion Resistance—There are numerous published data on the marine and chemical corrosion resistance of unalloyed titanium. Preliminary tests reveal that comparable results will be obtained with A-110AT. While no specific data have been obtained as yet, corrosion tests in fuming nitric acid have been encouraging.

Forming and Fabricating

Forgeability—The beta transus for A-110AT is in the 2000 F range. This also is the optimum forging temperature range. The high hot strength requires that forging temperatures be above those for other titanium alloys. However, the improved hot air corrosion resistance keeps contamination levels within the ranges of the other alloys.

Welding—Recent laboratory welding experiments conducted by Air Reduction Company indicated that A-110AT is just as weldable as RC-70. Improved performance was obtained using filler rod in the welding operation. Radiographs showed the welds to be sound, and all welds tested had excellent properties. A summary of their results is shown in a table.

Aircomatic welding was done using square butt joints with 3/32 in. root opening and grooved copper back-up strip; 1/16-in. dia unalloyed titanium filler rod; 305-315 amp and 31 v, 40 cfh argon in gun and 100 cfh argon in trailing shield; and a welding speed of 32-in./min.

Heliweld joints were made with filler strip sheared from edges of sheet to give as close to 3/32-in. square cross-section as possible. Joint preparation and back-up plate same as used for Aircomatic. Other conditions were: 40 cfh helium in holder; 100 cfh helium in trailing gas shield; ⅛-in. thoriated tungsten electrode with ⅛-in. arc length. Welding currents and welding rates varied from sample to sample because of physical size and shape of filler rods.

Availability

Currently, A-110AT sheet is being produced in gages of 1/10 in. or thicker only. Due to the aforementioned hot strength, rolling of gages thinner than 1/10 in. has been difficult. Successful sheets down to 0.025 in. thick have been produced on a pilot-production scale, and should be available as standard production items in the near future.

At the present time, rough forgings are available up to 2500 pounds. Standard bar and plate items are also being produced. The processing of wire is still in the pilot production stage, but experimental wire should be available in the near future.

Acknowledgments

We express our thanks to the Air Reduction Co. for permission to include the data obtained in their laboratory on weldability.

D. R. Luster, J. P. Catlin and B. L. Shakely contributed to the mechanical testing of A-110AT at Rem-Cru.

Picture Credits: American Welding and Mfg. Co., Kaiser Aluminum & Chemical Sales, Inc.

Two New High Temperature Coatings...

1 A Flame-Sprayed Cermet *Flame-spraying technique used to coat high temperature alloys with powdered cermets. Cermet has a high melting point but can be liquefied and applied by blowing through 5500 F oxyacetylene flame.*

2 A Weld-Through Ceramic *Comparative test of new NBS A-418 coating (bottom) and other high temperature coatings. After 25 hr exposure the NBS coating is sound and unchanged, while the others show various stages of deterioration.*

by ALEXANDER PECHMAN,
Ceramic Engineer, Ryan Aeronautical Co.

● DURING THE PAST four years, high temperature refractory coatings, 0.001 in. thick, have been successfully applied to thousands of Ryan components for jet, piston and rocket engines. Recently, the laboratory has developed flame-spraying of refractory materials, ceramic coating of large thin-walled jet structures, and welding through ceramic coatings.

Still in the research phase, flame-spraying is a spectacular operation in which powdered refractories are momentarily liquefied and sprayed on metal surfaces. For this work, a spray gun, designed for metal spray-welding purposes, was converted to the application of cermets or metal-ceramic powders.

Ryan has successfully flame-sprayed the cermet, nickel-magnesia, as a coating on stainless steel, Inconel and other high temperature alloys. This cermet is made from nickel and magnesium oxide which have been combined, sintered and ground to powder. As a coating it withstands temperatures up to 3500 F for limited periods.

Because of its high fusing temperature, nickel-magnesia cannot be applied to metal structures in ordinary furnaces since these are useful only to about 2100 F. Specially insulated furnaces are expensive and difficult to design and operate for handling sizable parts. Further, jet engine alloys cannot stand the necessary fusing temperatures without losing strength and suffering other undesirable physical changes. Flame-spraying overcomes these obstacles and avoids the use of expensive furnace equipment. The cermet is heated to the fusing point without bringing the base metal, to which it is applied, close to dangerously high temperatures.

Flame temperatures reach 3500 F in these afterburners for J-47 jet engines.

How It's Done

The nickel-magnesia powder is placed in a metal container attached to the flame-spraying gun and nitrogen forces the powder into the torch nozzle. Oxygen and acetylene are also piped to this nozzle where they burn with a temperature of 5500 F. As the cermet flows through the flame it liquefies and is sprayed on the metal surface where is cools, solidifies and adheres in a refractory coating which can be applied to prescribed thickness. Ryan has applied the coating in thicknesses ranging from less than 0.001 in. to 0.020 in. The base metal is not heated to temperatures high enough to cause warping or buckling.

Flame-sprayed cermets, as coatings, may broaden the applications for after-burner liners, rocket parts and other similar high temperature components. These parts must withstand high volocity impingement of corrosive gases at high temperatures but are not required to have high structural strengths. Their service life may be materially extended by successfully applied cermet coatings.

For use with high strength components, such as combustion chambers, transition liners and exhaust systems, cermet coatings may be the means of extending operating temperatures by as much as 150 F. Present ceramic coatings are limited to temperatures around 1800 F. Above 2000 F, cermets will probably not be used to coat these parts because the metals themselves will not retain sufficient strength to perform their functions.

"Hot parts" for jet engines of a Douglas F3D-2 Skynight have been successfully coated with high temperature ceramics.

Many metallurgists question the capacity of unprotected metals to meet the need at temperatures beyond those now experienced, or above 1800 F. This point seems to be about the limit of endurance for the known metals which are suitable for the applications.

Ceramic coatings offer the best promise of a solution. They gradually deform under stress at temperatures much higher than metals can sustain in service and are resistant to oxidation since they are saturated oxides of metals. However, ceramics

alone do not possess the structural strength and mechanical shock resistance of metals, and therefore ceramic coated metals are promising.

Ceramic Coating Successful

The first successful ceramic coating for high temperature steels was developed by the National Bureau of Standards in 1947, and had a coefficient of thermal expansion closely matching the stainless steels. Consequently, it adhered to them over a wide range of temperatures.

To determine their usefulness in actual service, a series of specially made exhaust system components were placed in service with Boeing Stratocruisers in transpacific flights. These exhaust "headers" were made from a variety of metals including stainless steels, Inconel X, Hastelloy C, Haynes Stellite N-155 and Armco 17-14 Cu-Mo. Some were coated with National Bureau of Standards ceramics and others were left uncoated. At intervals of approximately 800 hours the test headers were removed and inspected. Then, they were returned to service. Many of these components have now attained a service life of more than 3000 hr.

Metallographic examinations of the test headers have shown that the National Bureau of Standards ceramic coatings, of which A-418 is the most recent type, have retarded the occurrence of oxidation, carbon absorption and corrosion attack usually experienced in the application. As a result, the exhaust system components have had their service life extended from 50 to 100%.

In conjunction with California Metal Enameling Co., Ryan produces most of the ceramic coated exhaust equipment used by aircraft. Included in these applications are components for Boeing 377 Stratocruisers and C-97 Stratofreighters, Convair 240 and 340 Liners and Fairchild C-119 flying boxcars. Also, Ryan has built thousands of ceramic coated combustion chambers for General Electric J-47 jet engines and Continental engine manifolds for General Patton Tanks.

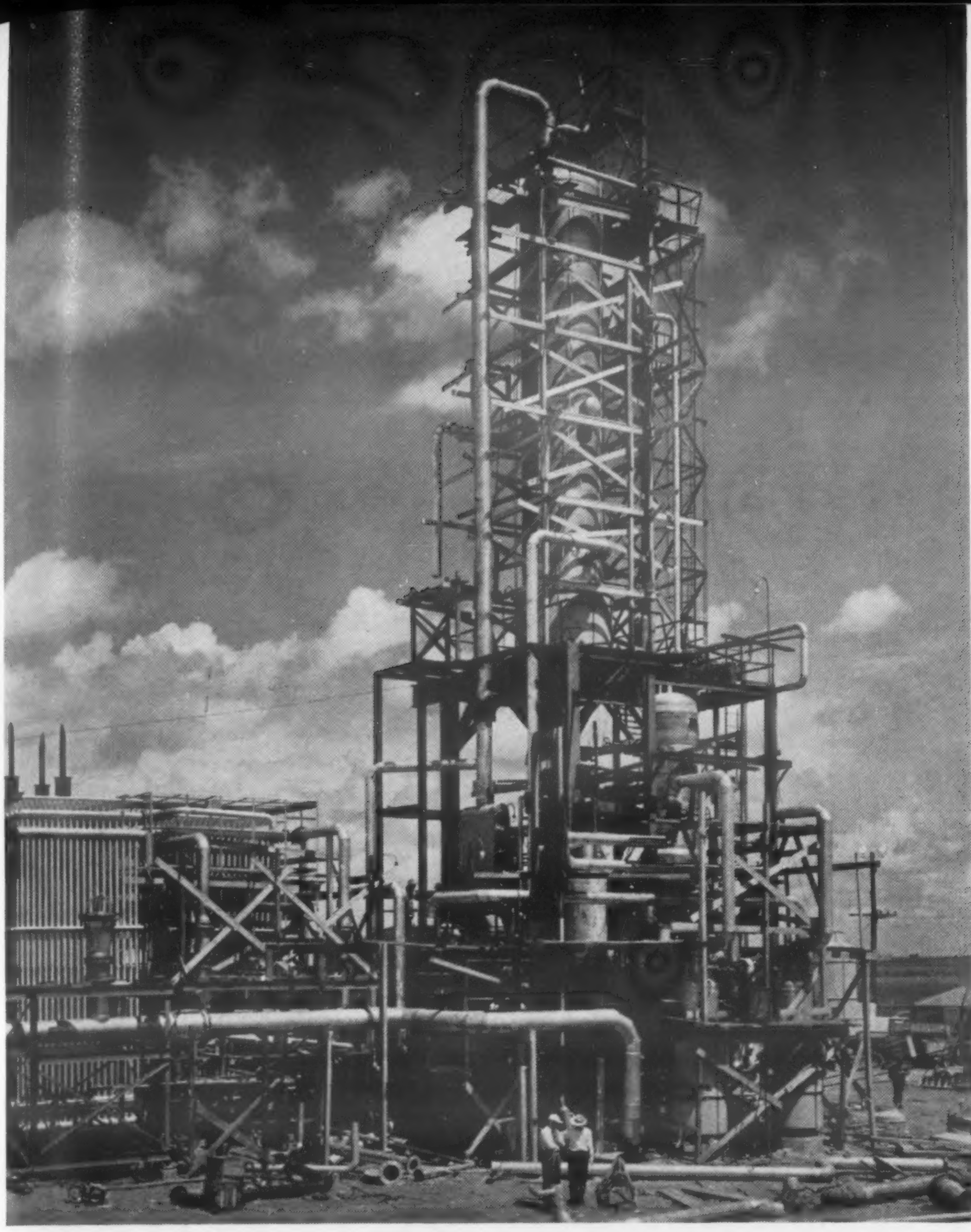
Ryan-Cameo have developed special cleaning, spraying and furnace-fusing techniques to ceramic coat large, thin-walled, corrugated structures for high temperature applications.

Large, thin-walled jet engine afterburner liners which require special treatment are also being produced successfully. Made of stainless steel, these structures shield the walls of General Electric afterburners from the destructive effect of the jet stream. They are thin-walled and would not resist the afterburner atmosphere if they were not ceramic coated on both sides. To provide extra strength and insulation properties the sections are louvered and corrugated. Designed by General Electric engineers, the liners are successfully extending afterburner life by maintaining a relatively cool boundary layer of gas against the walls. The A-418 ceramic coating protects the liner from the rapid oxidation which it would otherwise experience.

Because A-418 ceramic coatings are flux-like in character, it is possible to arc-weld through them with good results. This permits the building of large structures in small component parts and welding them together after they have been coated.

The ceramic coating melts, floats on the molten weld metal and combines with the welding flux. Along the weld zones, the adjacent ceramic material smoothly blends into the weld without spalling because of the good thermal shock resistance of the coating. This property is also effectively used in the fabrication of experimental jet engine assemblies which are partly ceramic coated, with uncoated portions within the structure.

Available ceramic materials are continually under test, in an apparatus utilizing a high octane fuel burner within test headers coated with the ceramic to be evaluated. Flame temperature is 2200 F. The ceramic is heated to 1700 F skin temperature for a period of 25 hr. In these comparative tests, A-418 ceramic coatings have displayed less physical change due to temperature than any other tested. The test facility is used also to assist the production departments in determining the proper thickness for coating specified parts or in deciding such questions as the optimum number of firings.



This all-aluminum oxygen plant operates at pressures as high as 110 psi and temperatures as low as −320F. Aluminum is used because of its good low temperature properties.

This 98-ft high tank was made of aluminum to prevent discoloration of the cellulose acetate stored in it. Capacity is 173,000 gal.

New Alloy Widens Future for Aluminum in Pressure Vessels

Higher design stresses make aluminum more competitive with other materials where corrosion resistance or lack of product contamination are important.

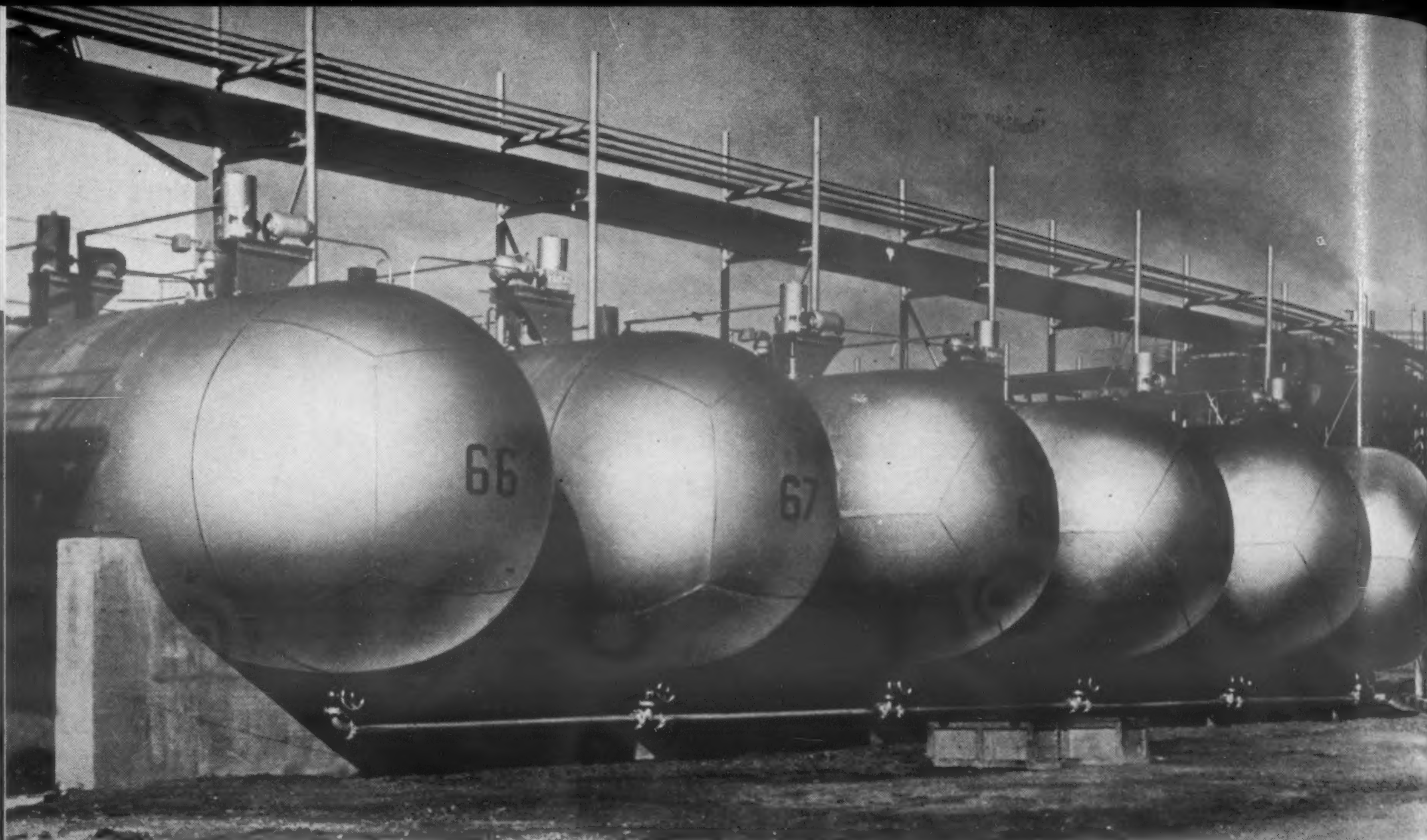
by JOHN B. CAMPBELL, Associate Editor, Materials & Methods

● THE PAST FEW DECADES have seen a steady growth in the use of aluminum alloys for chemical containers and processing equipment. Only in recent years, however, have aluminum alloys been approved under the ASME Boiler and Pressure Vessel Code, and, until 1952, 2S and 3S were the only alloys listed. The 1952 Code lists five additional sheet and plate alloys: 4S, 50S, 52S, 61S and high-purity (99.6%) BD1S. It also includes specifications for bolting materials, pipe, tube, forgings, bars, rods and shapes. Approval of 52S represented an increase of 87% in allowable design stress over that of 3S for welded construction.

Now, with the publication of Case No. 1174 a few months ago, a new and stronger aluminum alloy (see table for composition) has become available for use in unfired pressure vessels. The strongest commercial nonheat-treatable aluminum alloy yet offered, it allows welded design stresses 18% greater than in 52S and 120% greater than in 3S, the alloy heretofore most widely used for aluminum pressure vessels. The new alloy, designated GR40A by the ASTM and A54S commercially, is expected to expand the use of aluminum in unfired pressure vessels.

Why Aluminum?

Since there are many structural materials stronger and less expensive than aluminum, it is selected for an unfired pressure vessel only where it offers a significant technical or eco-



Aluminum replaced steel in these 58-ft long tanks used for storage of ammoniated ammonium nitrate. Tanks are 12 ft in diameter.

Synthetic glycerin can be shipped without contamination in this aluminum tank car constructed of ½- and ⅝-in. plates of 3S alloy.

nomic advantage that cannot be matched by another material at less cost. The most common reason for the selection of aluminum is its corrosion resistance. The economic importance of minimizing the rate of disintegration of equipment handling corrosive chemicals is obvious. Often, resistance to general external attack by the polluted plant atmosphere is important. Even where corrosion rates are too low to destroy equipment rapidly, contamination caused by corrosion products may pose a serious problem in quality control. In many pressure vessel applications where one of these factors is controlling, the choice of material narrows down to stainless steel or aluminum. Where product contamination is controlling, aluminum offers the peculiar advantage of colorless corrosion products.

Other advantages of aluminum in

pressure vessels are discussed briefly below:

Non-Sparking—The non-sparking characteristics of aluminum are often considered advantageous in the handling of highly inflammable chemicals.

High Reflectivity — Aluminum's high reflectivity of radiant heat and light often suggests its use for storage tanks containing volatile chemicals.

High Thermal Conductivity — As indicated by Table 1, aluminum has much higher thermal conductivity than most structural materials used in unfired pressure vessels. This factor has limited significance in thin-wall heat transfer applications but is of some importance in thick-wall vessels.

Light Weight—Comparison of densities and allowable design stresses in Table 1 shows that aluminum offers significant weight savings over copper and nickel, but relatively small savings compared to bronze, Monel and ferrous alloys. Even small weight savings, however, are sometimes important in transportation, particularly aircraft, where operating profits hinge on a favorable payload ratio.

Low Temperature Properties—Like the other nonferrous metals, aluminum undergoes no marked change in ductility at low temperatures, and no impact test is required under the Code. An impact test is usually required for carbon and low alloy steels, and in many cases, for stainless steels when service temperatures are expected to be lower than –20 F. As the accompany graph shows, the yield strength and ductility of 3S increase gradually with decreasing temperature, and tensile strength increases markedly below —100 F. Other aluminum alloys behave similarly.

The New Alloy

Maximum allowable design stresses for aluminum sheet and plate alloys now approved under the Code are listed in Table 2. For operating temperatures up to 100 F, the maximum allowable stress in tension for A54S is 7350 psi, for 52S it is 6250 and for 3S only 3350. These values apply to the annealed (0) temper. Higher design stresses, representing various degrees of strain hardening, are approved under the Code. However, they cannot be applied to welded construction, since no more than an annealed temper can be assumed in the weld zone after fabrication. Almost all pressure vessels are now fabricated by welding.

A good approximation of the increase in wall thickness needed in replacing a stronger material with aluminum can be obtained by comparing the allowable stress values listed in the first column of Table 1. With Type 304 stainless, for example, the inverse ratio of allowable design stresses is 18,750/7350 or 2.55. Hence, at room temperature, the

This 160,000-gal acetic acid storage tank was fabricated from aluminum plates ranging in thickness from 5/16 in. at the top to 9/16 in. at the bottom.

Table 1—Characteristics of Some Alloys Used in Unfired Pressure Vessels

Alloy	Allowable Design Stress, Psi (at Ordinary Temperatures)	Mod of Elast, 10^6 Psi	Specific Gravity	Thermal Cond., Btu/sq ft/F/hr/ft	Approx Cost Factor for Plate	Approx Materials Cost Factor*
Carbon Steel SA-201-A	13,750	30	7.8	29	4	0.2
Nickel Steel SA-203-B	17,500	30	7.8	19	4	0.2
Stainless Steel (304) SA-167-3	18,750	30	7.9	10	40	1.7
Copper SB-11	6,700	17	8.9	195	47	6.2
Aluminum Bronze SB-169	22,500	17	7.6	35	64	2.2
Nickel SB-162	10,000	30	8.9	35	85	7.6
Monel SB-127	17,500	26	8.8	15	67	3.4
Aluminum (3S) SB-178-M1A	3,350	10	2.7	90	32	2.6
Aluminum (A54S) SB-178-GR40A	7,350	10	2.7	85	37	1.4

$$* \text{ Materials Cost Factor} = \frac{\text{Specific Gravity} \times \text{Plate Cost Factor} \times 100}{\text{Allowable Design Stress}}$$

This factor is a rough estimate of the relative cost of various materials for unfired pressure vessels where pressures do not exceed 1000 psi.

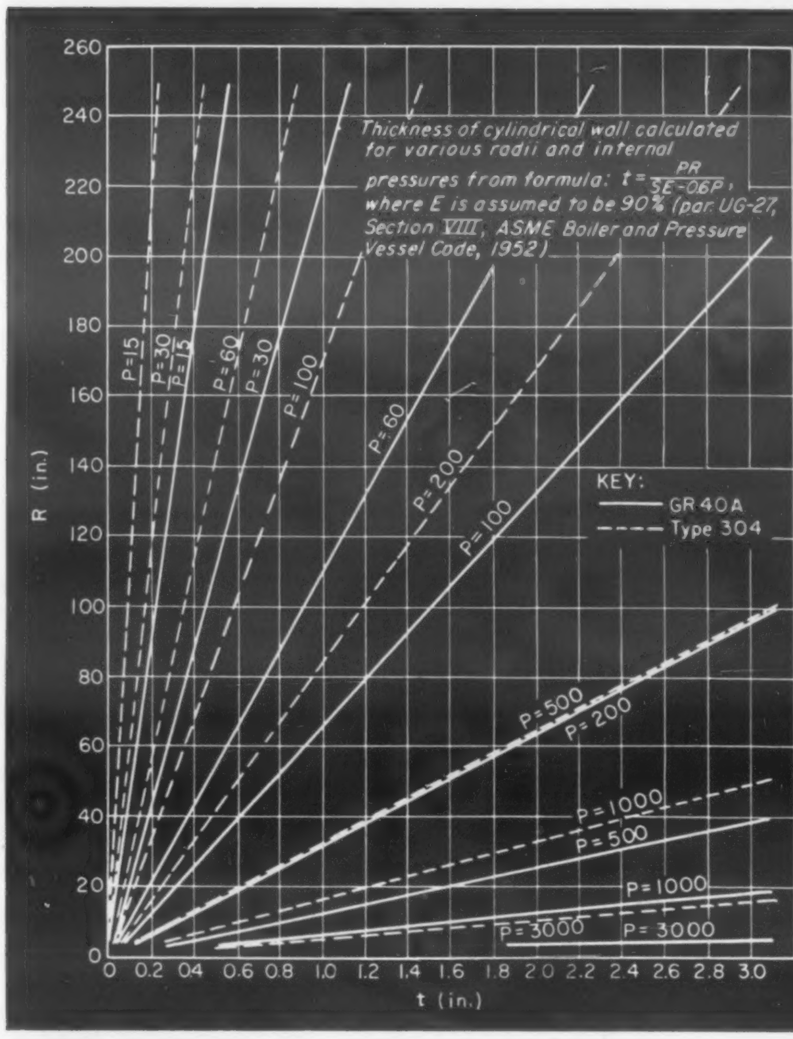


Fig 2—Relative thickness of aluminum and stainless steel unfired pressure vessels.

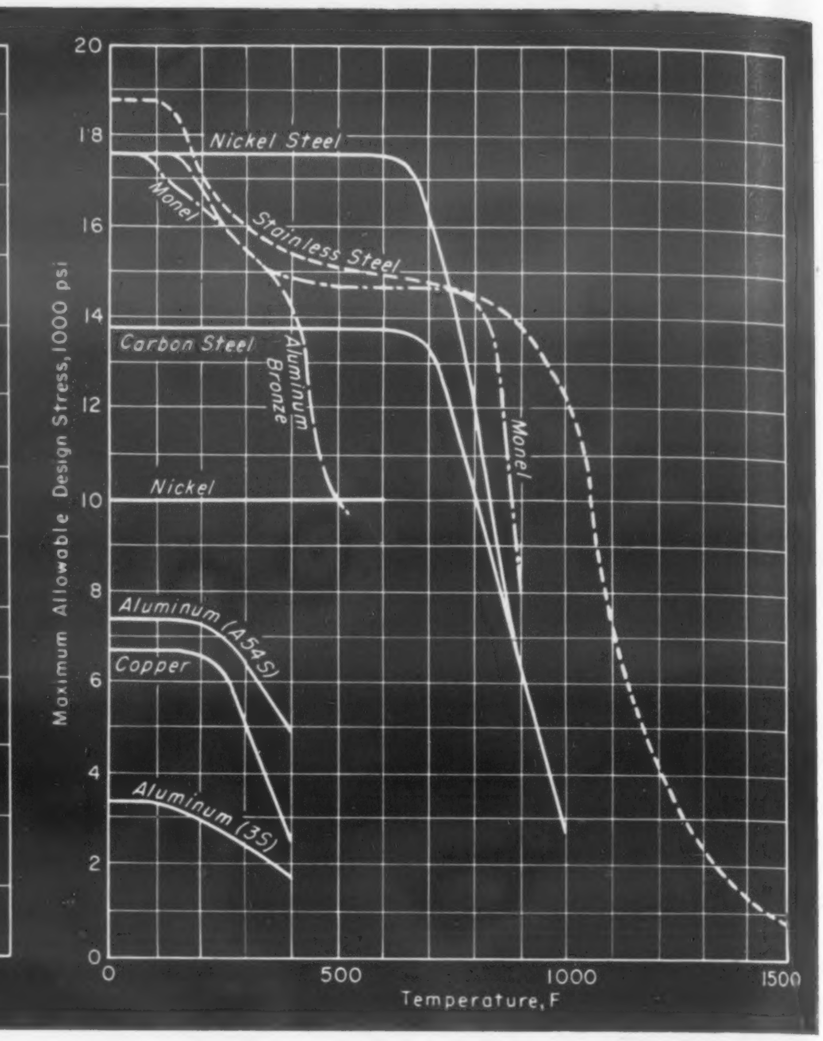


Fig 3—Allowable design stress vs. temperature for aluminum and other metals used in unfired pressure vessels.

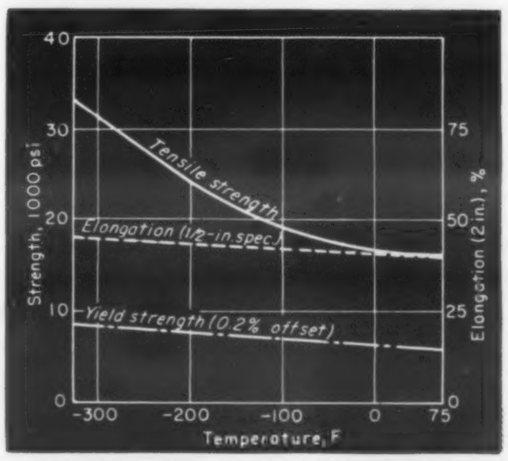


Fig 1—Tensile properties of aluminum alloy M1A (3S) at subzero temperatures.

thickness of an aluminum pressure vessel must be about two and a half times that of a stainless steel vessel. The curves in Fig 2 were calculated from the more exact formula used in pressure vessel design. They show that as pressures increase the stronger metal gradually increases its advantage over the weaker. Where operating pressures are relatively low and the vessels are fairly large, the ratio is substantially reduced in actual construction since the minimum thickness of the stronger metal is determined by fabricating practice.

Like all other aluminum alloys, A54S is limited by the Code to a maximum service temperature of 400 F. As Fig 3 indicates, the allowable design stress for this alloy falls off fairly rapidly for service temperatures above 200 F. In the range from 100 to 300 F, however, the ratio of its maximum allowable design stress to that of stainless steel is higher than at room temperature. The favorable low temperature properties of aluminum alloys make it possible to use them for applications where temperatures may go as low as −325 F.

The modulus of elasticity of aluminum alloys is only one-third that of ferrous alloys. By conventional design formulas it can be calculated that the thickness of an aluminum alloy shell must be about 40% greater than that of a ferrous alloy shell to insure equal rigidity of the wall. Since this figure is well within the increase in thickness required by a consideration of bursting strength, the difference in modulus, despite its magnitude, is not highly significant in pressure vessel design.

It is difficult to generalize on costs. One factor is the cost of materials. A rough idea of the relative costs of some materials used in unfired pressure vessels can be obtained from the last column in Table 1. Aluminum alloy A54S appears to be the least expensive of the corrosion-resistant materials, although stainless steel is only slightly more expensive.

Another factor is cost of fabrication, of which welding cost is an important part. Welding cost increases substantially as metal thickness increases. Assuming an equal number of welds, therefore, the welding cost of ferrous vessels might be significantly lower than that of the thicker aluminum shells. Some-

Composition of A54S	
Magnesium	3.1-3.9
Chromium	0.15-0.35
Copper (max)	0.10
Manganese (max)	0.10
Zinc (max)	0.20
Iron plus Silicon (max)	0.45
Other, each (max)	0.05
Other, total (max)	0.15
Aluminum	remainder

times this economic advantage of stainless steel is reduced by the availability of larger plates in aluminum and the consequent need for fewer welds.

Fabrication

The formability of A54S is comparable to that of 52S. Shop experience seems to indicate that, except where certain critical forming operations are needed, the new alloy can be formed on equipment developed for 52S and 61S alloys. In general, the equipment found in most steel tank shops can be used to form aluminum tanks.

Two welding processes—tungsten arc and consumable electrode, each argon-shielded — are recommended for aluminum pressure vessels. The consumable electrode process is often preferred because of the faster weld rate resulting in less distortion and weld cracking. The distortion problem is particularly critical in aluminum because its thermal coefficient of expansion is double that of steel. On the other hand, the tungsten arc process is usually needed for vertical or overhead welds. As a result of considerable development work in the last few years it is now possible to obtain butt joints of good quality on aluminum plate up to 3 in. thick.

Heads, nozzles and manholes for aluminum tanks can be purchased from many companies supplying comparable steel parts. Bolted connections are preferred to threaded from the standpoint of both service and maintenance. If a threaded connection must be used, and provided corrosive conditions are not too severe, it is usually recommended that a stainless steel threaded insert be used. Aluminum threads will not take the punishment they are likely to get from workmen used to dealing with steel vessels. If aluminum threaded joints are used, the joint compound must be compatible with aluminum.

The use of steel backing rings on flanged nozzles, manholes and removable heads is recommended since it permits the use of relatively thin aluminum flanges. By distributing the bolting pressure, such rings simplify the problem of obtaining a tight seal. Steel backing rings should be painted before assembly; where corrosion resistance is important the steel rings should be first zinc- or cadmium-plated. Forged flanges of 61S-T6 are often used and require no steel backing rings.

Table 2—Allowable Stresses for Aluminum Alloy Sheet and Plate*

Alloy**	Specified Min Tens Str, Psi	Specified Min Yield Str, Psi	Maximum Allowable Stress in Psi for Metal Temperatures Not Exceeding (in Deg F):						
			100	150	200	250	300	350	400
996A (BD1S)	9,500	2,500	1650	1650	1600	1450	1250	1200	1050
990A (2S)	11,000	3,500	2350	2350	2300	2100	1850	1600	1300
M1A (3S)	14,000	5,000	3350	3150	2900	2700	2400	2100	1800
MG11A (4S)	23,000	8,500	5650	5650	5650	5500	4650	3850	3150
G1A (50S)	18,000	6,000	4000	4000	4000	4000	4000	3350	2800
GR20A (52S)	25,000	9,500	6250	6250	6200	6000	5400	4650	3900
GR40A (A54S)	30,000	11,000	7350	7350	7350	7000	6400	5650	4900

* *Adaped from Table UNF-23, Section VIII, ASME Boiler and Pressure Vessel Code, and Case No. 1174. Welded construction is assumed; hence only annealed (0 temper) values are listed here.*
** *Subject to Specification No. SB-178.*

Insulation between aluminum and dissimilar metals is a practice that should be observed throughout construction. Tanks are usually insulated from dissimilar supports by several layers of asphalt or coal-tar paint. Additional insulation is provided by a layer of heavy roofers felt between the support and the tank. Faying surfaces should be sealed to keep out moisture.

Support for horizontal tanks should provide contact with the tank wall for at least 120 deg of the tank circumference. On vertical aluminum tanks with dished heads, tubular legs welded to both head and side wall provide suitable support.

Applications

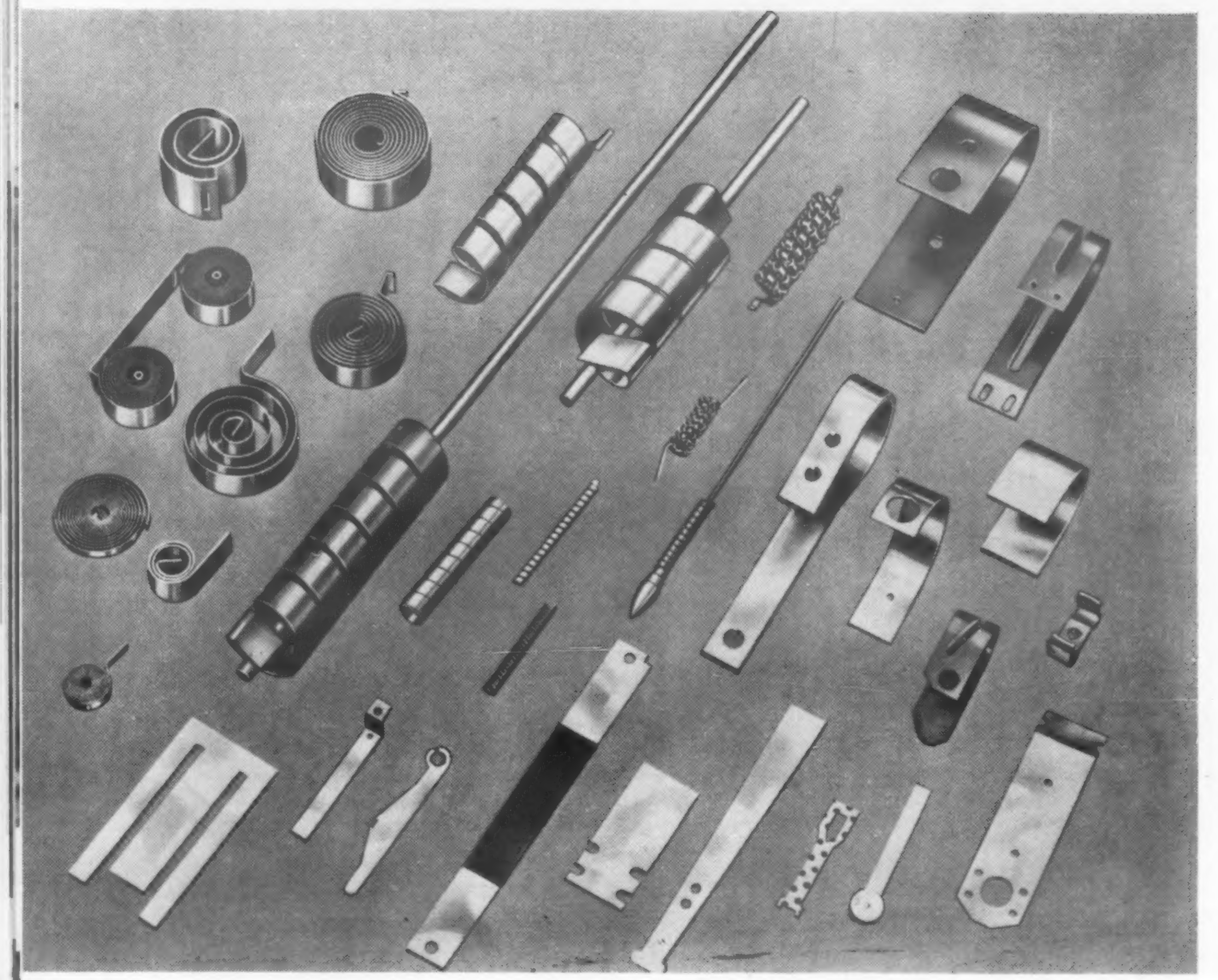
Aluminum pressure vessels are now being used in a great many different processing, shipping and storage applications. Equipment includes piping, heat exchangers, steam-jacketed kettles, pumps, stills, condensers, shipping drums, tanks for tank cars, and plant and field storage tanks. Chemicals handled include many foods, beer, 90% hydrogen peroxide, red fuming nitric acid, ammonium nitrate, formaldehyde, synthetic glycerol, phthalic anhydride, acetic acid, acrylonitrile, nylon salts, fatty acids and crude oils. Aluminum is also used in the manufacture of synthetic resins and textile fibers to avoid product contamination. Because aluminum is non-toxic it is used for fermentation equipment used in the production of chemicals by micro-organisms.

In many environments, of course, the use of aluminum would not even be considered. Aluminum alloys are attacked by alkali and alkaline earth hydroxides, such as sodium and calcium hydroxides, and by certain strong mineral acids, such as hydrochloric acid. Other chemicals inimicable to aluminum include methylchloride and compounds of copper, nickel, mercury and lead.

Acknowledgment

The assistance of the Aluminum Co. of America in the preparation of this article is acknowledged with appreciation.

This vessel was designed as a scrubbing tower to be used for hydrogen sulfide recovery in a petroleum refinery. Design pressure was 25 psi and wall thickness is ⅜ in.



Typical thermostat metal coils and formed parts, usually fabricated in a temperature controlled work area to insure accurate and consistent performance.

Where and How Thermostat Metals Are Used

Though most industries do not manufacture their own thermostatic controls, it is important for the engineer to know the materials and principles involved, in order to intelligently select them.

by MALCOLM W. RILEY, Assistant Editor, Materials & Methods

● THE BASIC FUNCTION of a thermostat metal is to convert heat into mechanical work. This is accomplished by its reaction to heat. A thermostat metal consists of two or more metals of differing coefficients of expansion which have been bonded together into a composite sheet or strip. The metal with the higher coefficient tends to expand to a greater extent than the one with the lower, and the resulting deflection of the strip creates a usable force. This force is utilized in various types of controls to perform three basic types of operation: 1) temperature indication, as in thermometers; 2) temperature control, as in furnace controls; and 3) compensation for temperature change, as in voltage regulators. To serve these functions, thermostat metals made of a wide range of alloys are produced today in a myriad of shapes and sizes.

Alloy Selection

In selecting a thermostatic device, the first consideration is the maximum temperature to which it will be exposed. The second is the temperature range of sensitivity within which the device is to operate. At the present time the maximum temperatures to which thermostat metals may safely be subjected are around 1000 F, though most common elements operate in a range of approximately 50 to 300 F.

Since the deflection, and therefore the force exerted, is due to the difference in the coefficients of expansion of the component metals, this factor is one of the important considerations in selecting the alloys which make up the strip. The greater the difference in coefficients of expansion, the greater the deflection. In addition, it is necessary that the coefficients be reversible; that is, the alloy after expanding with heat, must contract to the same extent on cooling. Only in this way can reliable duplication of results be obtained once the instrument is calibrated. Alloys used, therefore, are restricted mainly to solid solution alloys, precluding those that exhibit changing solubility or phase changes with temperature changes.

It would be impossible to list here all the alloys used in thermostat metals because of the great number of combinations, each of which possesses slightly different properties, suitable for certain applications. However, there are some broad classifications that can be mentioned.

Ever since 1897, when Invar, the 36% nickel-iron alloy was discovered, it has been used generally for the low expansion side since it has a coefficient of expansion of almost zero in a temperature range of 0 to 300 F. Above this temperature range its expansivity increases until it approaches that of iron. But this range is satisfactory for a great many applications of thermostatic controls.

For higher temperatures or for particular applications, modifications of Invar are used. By increasing the nickel content, the temperature range of low expansivity can be increased.

For instance, an Invar type alloy of 42% nickel, although there is some increase in expansivity, has a low coefficient of expansion up to 600 F. These Invar type alloys can also be modified by the addition of chromium, molybdenum or cobalt for high temperature strength and resistance to scaling.

One of the first alloys used for the high expansion side of thermostat metal was brass. Though still in use, it is somewhat limited because of its low range of thermal sensitivity (up to 300 F), and its softness which, when in combination with the relatively hard Invar alloys, presents difficult processing problems.

Other alloys used for the high expansion laminate range from the plain carbon ferritic steels of medium deflection having coefficients of expansion of around 7 x 10^{-6} per deg F, through the chromium-nickel stainless austenitic group having expansivities of 8 to 10 x 10^{-6} per deg F, to special alloys like the more recently developed high manganese-nickel-iron alloy with a 50% higher coefficient of expansion than existing nickel-chromium alloys. This alloy also has high electrical resistivity, making it particularly useful in electrical applications, as will be pointed out later.

Beyond this, generalization is impractical. Each alloy is selected to suit a particular application and to work under specific conditions. As well as coefficients of expansion and temperature limitations, there are other properties of similar importance in the business of alloy selection.

Thermal Bending

The thermal bending of a thermostat metal is affected by the difference in coefficients of expansion, the ratio of elastic moduli, and the thickness of the component metals. It is mathematically expressed by a general equation which, for the purposes of this article, need not be expressed here. Suffice it to say that the radius of curvature of a strip is directly proportional to the difference in the coefficients of expansion of the component metals and the temperature change, and is inversely proportional to the thickness of the strip. It is immaterial which component has the larger modulus of elasticity so long as the ratio is the same. This ratio can vary from 0.3 to 3.3 and the element will still maintain 91% maximum curvature (thermal activity). Combinations having too great a difference in moduli, as Invar-cadmium, or Invar-hard rubber, have very little or no thermal activity.

The work that a thermostat metal can do is proportional to the square of the difference in coefficients of expansion and proportional to the modulus of elasticity. To obtain the maximum work from a thermal element, the thicknesses of the components should be inversely proportional to the square roots of the moduli of elasticity. Therefore, the optimum combination is obtained when the moduli are equal. At this point the thickness of the components will also be equal, and no improvement in performance is possible by varying these factors. And the higher the modulus or stiffness, the more efficient the element will be.

Stress Problems

The hazards of excessive stresses are obvious. When the combination of thermal and mechanical stresses exceeds the elastic limit of the thermostat metal a permanent set occurs. This set changes the calibration of the device and may render it unusable.

It is difficult to determine accurately the maximum stresses allowable for thermostat elements at various temperatures. Stresses in the element are due to thermal changes, mechanical loading, and fabricating operations such as bonding, rolling, slitting, flattening, and heat treating. The first two are relatively simple to determine, but the last is almost impossible, therefore, a healthy safety factor must be allowed.

For most thermostat metals having ferrous alloys for both components, the following maximum allowable working stresses can be used:

Temperature, F	Allowable Working Stress, f
75	50,000
300	49,000
500	43,000
700	6000
900	2000
1000	0-1000

Substituting the above values for f, the following equation can be used to determine the allowable working loads for cantilever elements and helix- and spiral-coil elements:

$$P = \frac{fwt^2}{6L \text{ (or R)}}$$

where P = allowable load, lb
f = allowable working stress, psi
w = width, in.
t = thickness, in.
L = Length of cantilever, in.
R = radius arm of helix or spiral coil

These allowable stresses are approximate only and should be used with caution.

Electrical Resistivity

An increasing number of today's electrical control devices such as thermal relays, circuit breakers and motor overload protectors are actuated by thermostat metal elements. The current passing through the strip generates heat, which in turn causes the deflection of the strip, thereby actuating the device. This type of operation requires elements with a wide range of electrical resistivity since the amount of heat generated depends on this factor.

Elements manufactured today have electrical resistivity ranging from 20 to 850 ohms per circular-mil-ft at 75 F. The highest range of resistivity was made possible by the development of the high manganese alloy, which by itself has a resistance of 1050 ohms per circular-mil-ft. For those elements with resistivity over 500 ohms per circular-mil-ft, the nickel-chromium, nickel-chromium-aluminum-iron and nickel-manganese-aluminum-iron alloys are used.

In filling in required resistivities ranging from 470 to 20 ohms per circular-mil-ft, a third metal strip is added between the two components. This strip is made of a metal of varying resistivity and thickness to provide the precise conductivity necessary. The resistivity of these "tri-metallic" elements can be calculated by considering the three strips as a parallel circuit. Another factor that should be kept in mind is that the resistivity of a metal changes with temperature change, and the resistance at the operating temperature and the rate of increase with temperature rise (coefficient of resistance) is equal in importance to that at room temperature.

Other Properties

Other properties which affect the selection of the alloys for use in a thermostat metal, but which will not be dealt with extensively here are corrosion resistance, thermal absorptivity, thermal conductivity, and specific heat.

The amount of consideration given to the corrosion resistance of the

element depends on the intended application of the unit. Since a great many of the thermostat metals are made of alloys in the stainless steel class, they will normally resist the corrosion effects of domestic and industrial atmospheres. For applications which require immersion in steam or liquids, care should be taken in selecting alloys with increased chromium content to get the optimum protection.

In some cases, electroplating the element with nickel, zinc, cadmium or other such metals, or dip-coating with lead or tin has been successful. However, any coating process will reduce the thermal activity of the element.

For those thermostat metals which employ ambient temperatures as the source of heat, the surface of the element should possess maximum absorption: i.e. matte finish. The thinner the element, the finer the finish should be.

In cases where the heat is transferred to the element through the mounting fixture, the thermal conductivity of the metals used is an important factor. Thermal conductivities of most metals and alloys are roughly proportional to their electrical conductivities, therefore a rough approximation of thermal conductivity can easily be made.

The specific heat of the metals used is important, but not much choice is available, since most thermostat metals have specific heats very close to 0.12 Btu per lb per deg F.

The thermostat metals are stress relieved and stabilized after the various manufacturing operations such as rolling, slitting, bonding, flattening, and fabricating of the finished part.

Typical Applications for Thermostat Metals

	Response Due To			Results Obtained			
					Temperature Control		
	Ambient Temperature	Auxiliary Heating	Internal Heating	Temperature Indication	Temperture Control	Temperature Limitation	Temperature Compensation
CIRCUIT CONTROL AND PROTECTIVE DEVICES							
Appliance Cord Controls	X		X		X		
Circuit Breakers	X	X	X				X
Fluorescent Lamp Starters	X	X					X
Generator Cutouts	X						X
Oil Burner Controls	X	X	X		X	X	X
Overload Relays	X	X	X				X
Stack Controls	X				X	X	
Thermal Cutouts	X						X
Transformers	X			X			
Voltage Regulators	X						X
MECHANICAL DEVICES							
Automatic Chokes	X						X
Fluid Valves	X				X	X	
Gas Burner Controls	X	X					X
Piston Rings	X				X		X
Shock Absorbers	X						X
HEATING DEVICES							
Air Conditioners	X				X		
Commercial Cooking Devices	X			X	X	X	
Electric Coffee Makers	X				X		X
Electric Flat Irons	X			X	X	X	X
Electric Blankets	X	X			X	X	
Hot Water Limit Switch	X					X	
Roasters	X			X	X	X	
INSTRUMENTS							
Alarm Devices	X			X			
Altimeters	X						X
Meteorological Devices	X	X		X			X
Thermostats	X				X		
Thermocouple Pyrometers	X						X

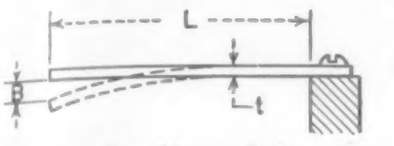
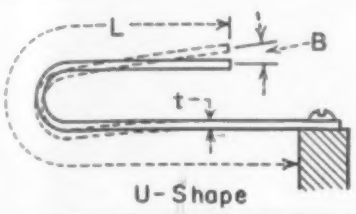
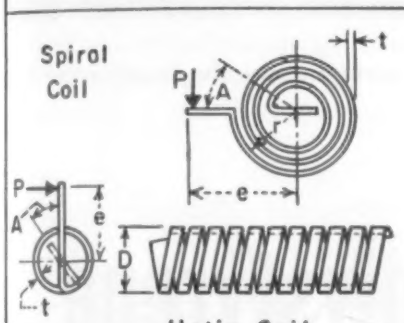
Bonding

There are three types of bonding processes which can be used in joining the laminates. An alloy with a lower melting point can be cast on one with a higher. This can be used only where there is a great difference in melting points. Another method is brazing. The difficulty here lies in the fact that the filler metal leaves a weak joint between the two components. The third type, and the one which is in most common use today, is welding in the solid state. In this last process, the metals are pressed together and reduced by a series of rolling and annealing operations until the desired gage is obtained. With this reduction, a permanent intermetallic bond is assured.

Reversed Thermostat Metal

For some specialized applications the reversed thermostat metal has been developed. This element is made up of two strips of normal thermostat metal butt welded with the high and low expansion sides reversed.

One of the important factors in the manufacture of these elements is confining the weld area to a sharply defined section of the strip. The metals used in the two strips must also possess similar properties,

Formulas to Determine Delection Force, and Stress of Thermostat Metal Element				
Forms	Deflection	Force	Restrained Force	Stress
 Cantilever Strip	$B=\frac{c_2(T_2-T_1)L^2}{t}$	$P=\frac{a_2 B w t^3}{L^3}$	$P=\frac{a_2 c_2 (T_2-T_1) w t^2}{L}$	$S=\frac{6PL}{wt^2}$
 U-Shape	$B=\frac{c_2(T_2-T_1)L^2}{2t^1}$	$P=\frac{4 a_2 B w t^3}{L^3}$	$P=\frac{2 a_2 c_2 (T_2-T_1) w t^2}{L}$	$S=\frac{3PL}{wt^2}$
 Simple Beam or Disc	$B=\frac{c_2(T_2-T_1)(L^2 \text{ or } D^2)}{4t}$	$P=\frac{16 a_2 B w t^3}{(L^3 \text{ or } D^3)}$	$P=\frac{4 a_2 c_2 (T_2-T_1) w t^2}{(L \text{ or } D)}$	$S=\frac{3PL}{2wt^2}$ for simple beam only
Spiral Coil  Helix Coil	$A=\frac{c_1(T_2-T_1)L}{t}$	$P=\frac{a_1 A w t^3}{Lr}$	$P=\frac{a_1 c_1 (T_2-T_1) w t^2}{r}$	$S=\frac{6P(r+e)}{wt^2}$

t – Thickness, in.	b_1 – Torque-temperature constant, coils	A – Angular rotation, coils, deg
w – Width, in.	b_2 – Force-temperature constant, strip and U-shape	P – Force, lb.
L – Active length of strip, in.	B – Deflection, strip, in.	e – Radius at point load is applied, in.
D – Diameter of disc, in.	c_1 – Thermal deflection constant, coils	(T_2-T_1) – Temperature change, F
a_1 – Torque constant, coils	c_2 – Thermal deflection constant, strip and U-shape	s – Stress, psi
a_2 – Force constant, strip and U-shape	r – Radius of outside coil, in	F – Flexitivity, ASTM value 50-200F

such as electrical resistivity and chemical composition, and melting point. Those with differing compositions and properties are difficult to weld satisfactorily. When the two strips to be reversed differ in thickness lap welding is used. However this kind of reversal is not as satisfactory as the butt welded type.

The applications of reversed thermostat metal fall into three categories: compensation, straight-line motion, and positive make-and-break. The construction of these is shown in an accompanying illustration.

The thermostat in a flat iron is an example of the reversed thermostat metal used to compensate for thermal overshoot and thermal lag, thus ensuring accurate maintenance of the temperature desired in the iron. In some types of flame detectors or stack controls for domestic oil burners, straight line motion of the thermostatic element is necessary for the efficient operation of the control. Since the common types of thermostat metal elements do not give linear motion if the temperature range is relatively wide, as in domestic oil burners, the reversed element is used.

A normal cantilever thermostat metal element is essentially a creep device, slow in operation. With this gradual movement, in make-and-break devices, a slight vibration may well cause arcing across the contacts. The use of the reversed thermostat metal speeds the operation and ensures a positive make-break action.

Acknowledgments

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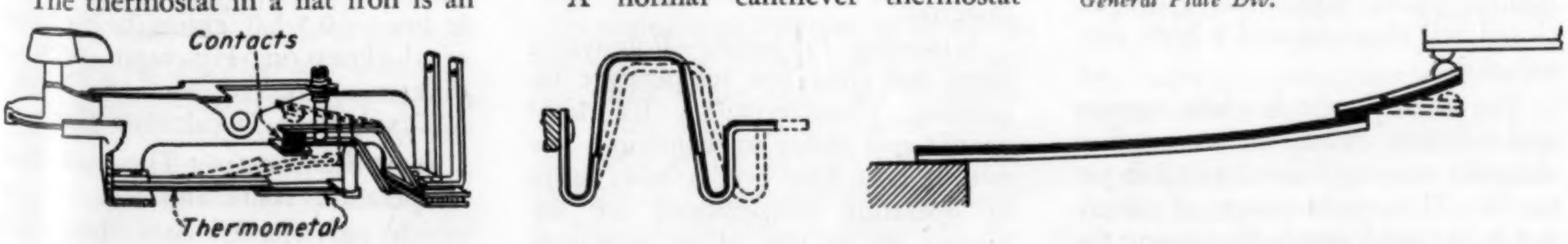
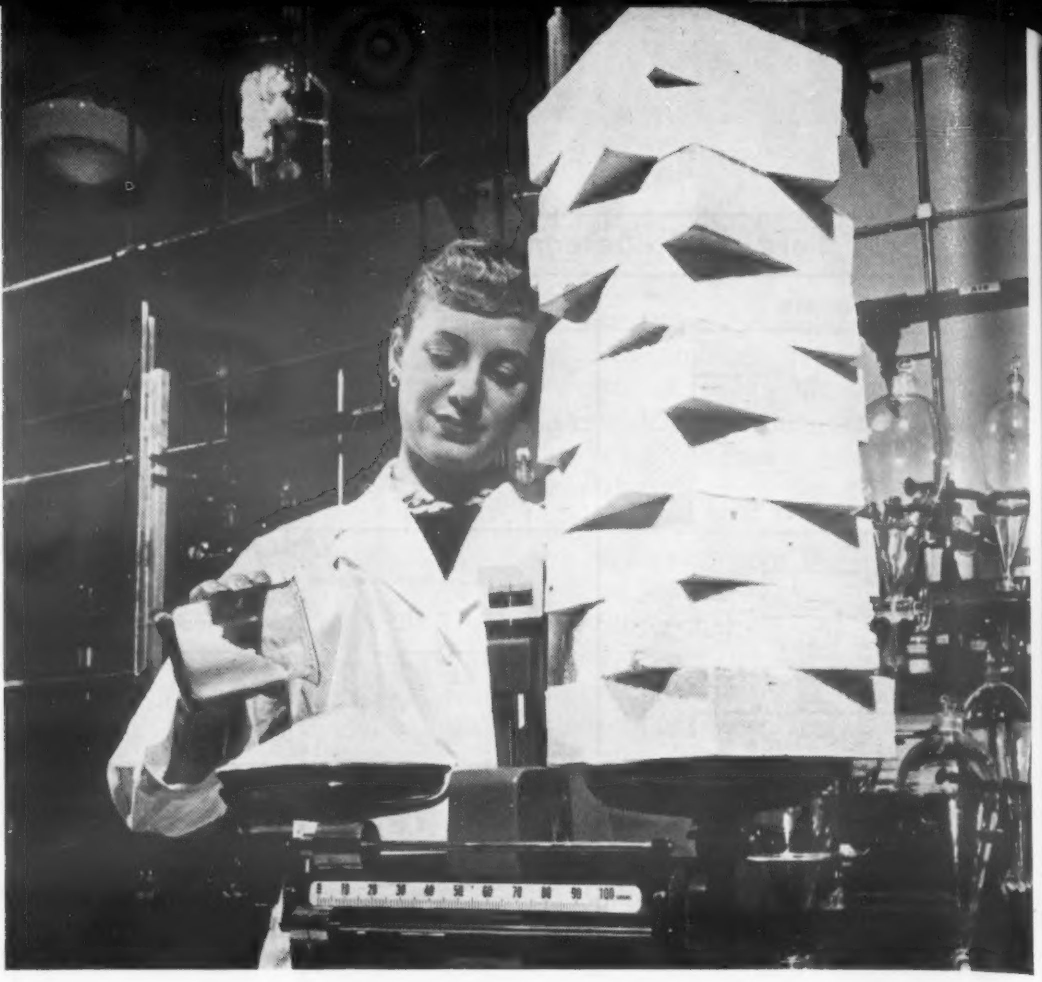
Picture Credit: Metals & Controls Corp., General Plate Div.



The operations of reverse-welded thermostat metals are shown here. To the left is a compensated cantilever design; center, a double reverse-welded structure illustrating straight line motion; and to the right, a positive make-break action device. The dark side is the high expansion side.

Good insulation qualities, high strength-to-weight ratio, and relatively good toughness make this new foamed plastic promising for many uses.

—A New Materials Preview



Starting as tiny beads (left) the plastic expands many times original size (right) when heat is applied.

New Expandable Polystyrene . . .

● A FOAM-TYPE polystyrene plastic has just been announced by Koppers Co., Inc. Developed by their Research Dept. and Chemical Div., the new material, starting as tiny beads, can be expanded in heated molds into various sizes and shapes. This ability to be molded plus other properties, including light weight, low thermal conductivity, controllable density and low water absorption, should make polystyrene foam plastic useful for thermal insulation, sandwich construction, buoyant products, and toys and novelties.

The new material is supplied in the form of free-flowing, small, hard polystryrene beads impregnated with a special foaming agent. When heat is applied to these beads in a closed mold, they expand to produce a foamed plastic which has a discrete closed cell structure and a high density skin.

The foam plastic is white, opaque and odorless. It can be produced in densities ranging from 2 to 10 lb per cu ft. This wide range of densities is obtained simply by varying the quantity of beads placed in the mold.

The unexpanded polystyrene beads cost about 60 cents per lb. Based on this price, the material cost of the expanded plastic in densities from 2 to 10 lb per cu ft runs from about 10 to 50 cents per board foot.

Properties

Strength Properties—The mechanical properties of polystyrene foam of various densities are given in the accompanying table. The mechanical properties vary somewhat with temperature since it is thermoplastic. The values in the table are for foams at room temperature and will decrease slightly as the temperature approaches the heat distortion point. The high density skin formed when the plastic is foamed in a mold, enhances the strength properties and provides a surface toughness which resists crushing of the expanded material.

Insulating Properties—Polystyrene foam has good low temperature insulating characteristics. Its light weight and ability to maintain a low rate of heat flow over a wide range of operating temperatures are important in its use as an insulating material.

The values on thermal conductivity given below are typical of those obtained at a density of 2.5 lb per cu ft and a cell size of 0.002-0.006 in. by the guarded hot plate method. Thermal conductivity varies with changes in cell size and density of foam. An increase in density results in a slight increase in the rate of heat flow. The reverse holds true when density is decreased.

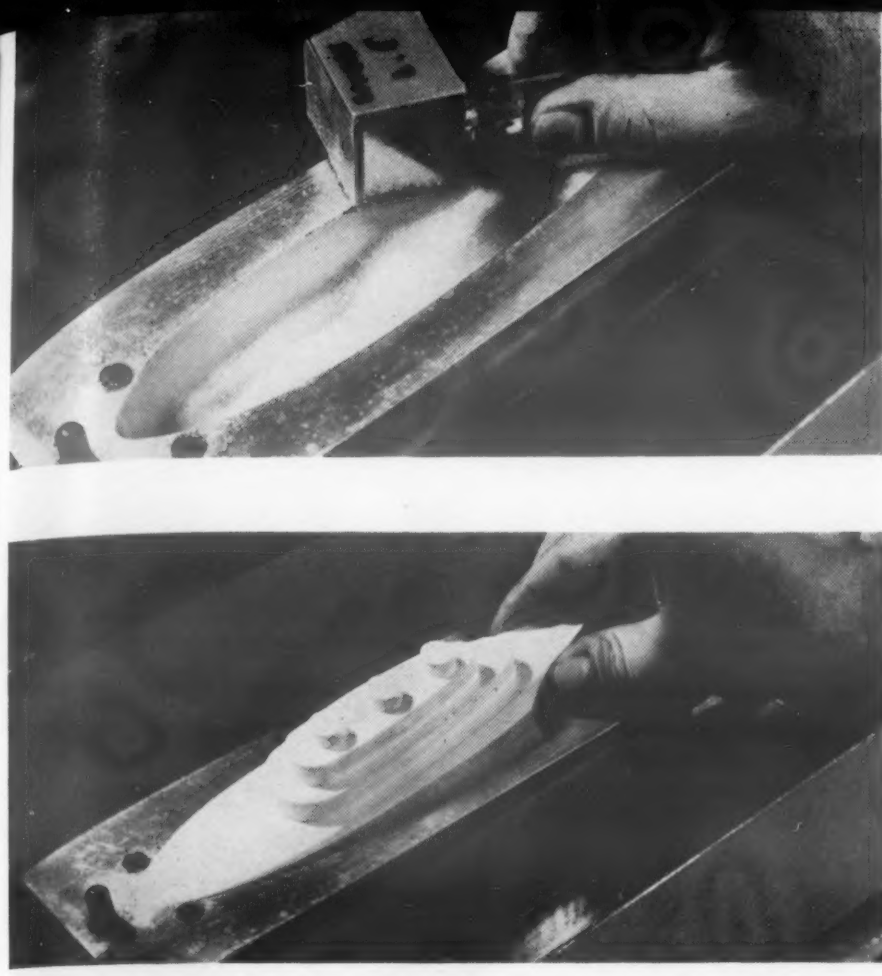
Thermal Conductivity

(Btu/hr/sq ft/°F/in.)

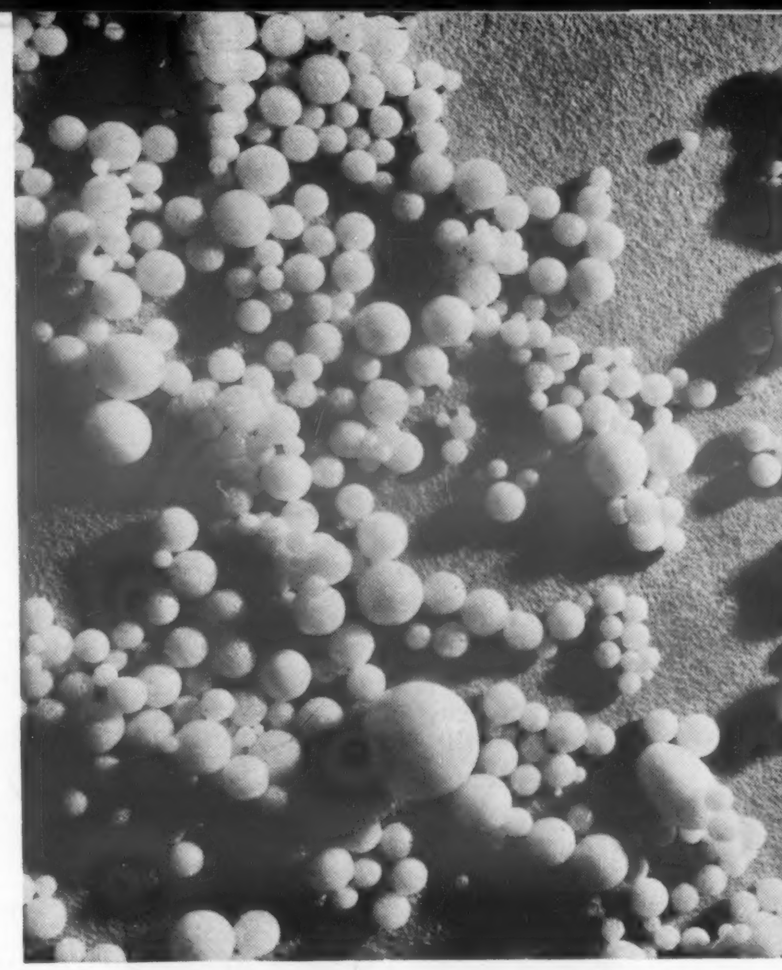
Av. Mean Temp.	19.9F	75F	120F
	0.214	0.243	0.267

The water vapor permeability of a substance is important from the insulation standpoint. It is a measure of the extent to which a material will function as a "vapor barrier" between areas having different atmospheric conditions. The water vapor transmission rate of polystyrene foam is low — 0.5-1.0 grains/hr/sq ft/in. of thickness/in. Hg vapor pressure difference. ASTM Method D 697-42T was used to calculate the rate.

Heat Resistance — The maximum temperature for continuous use to which polystyrene foam should be exposed when not under load is 175 F. This value was determined by subjecting the specimen to dry heat



A small quantity of polystyrene beads placed in a mold into which steam is later injected (top) expands to fill the closed mold and produces molded shapes such as this boat (bottom).



How beads look when expanded outside a mold. Inside molds they crush together and adhere to each other.

. . . Can Be Molded

under no load for 24 hr and noting the highest temperature at which no distortion by heat alone took place. The foam burns at the rate of 4-5 in. per min when tested using ASTM Method D 635-44. An open flame is necessary for ignition, and free access to air is needed for continued burning.

Water Absorption—The water absorption is extremely low. Its non-inter-connecting cell structure prevents the absorption of water into the interior of the molded article by capillarity. Water absorption is less than 0.5% by volume after immersion for 8 days at room temperature. Under a hydrostatic pressure of 10 ft of water for 48 hr, absorption is less than 1.5% by volume. This water is absorbed only at the surface of the piece and is readily lost to the atmosphere once the article is removed from the water. This low water absorption combined with light weight makes this material desirable for use in buoyant members of boats, rafts, etc. Because of its low water absorption, buoyant properties are retained after prolonged immersion.

Electrical Characteristics — The electrical properties of polystyrene foam are being determined. However, it is expected that the dielectric constant and power factor will be very low.

Joining and Fabricating

Polystyrene foam can be successfully bonded to itself and a variety of other materials with a number of commercially available adhesives. Adhesives which contain any appreciable quantity of solvents for polystyrene should be avoided as these solvents will rapidly attack the expanded material causing shrinkage and collapse of the foam.

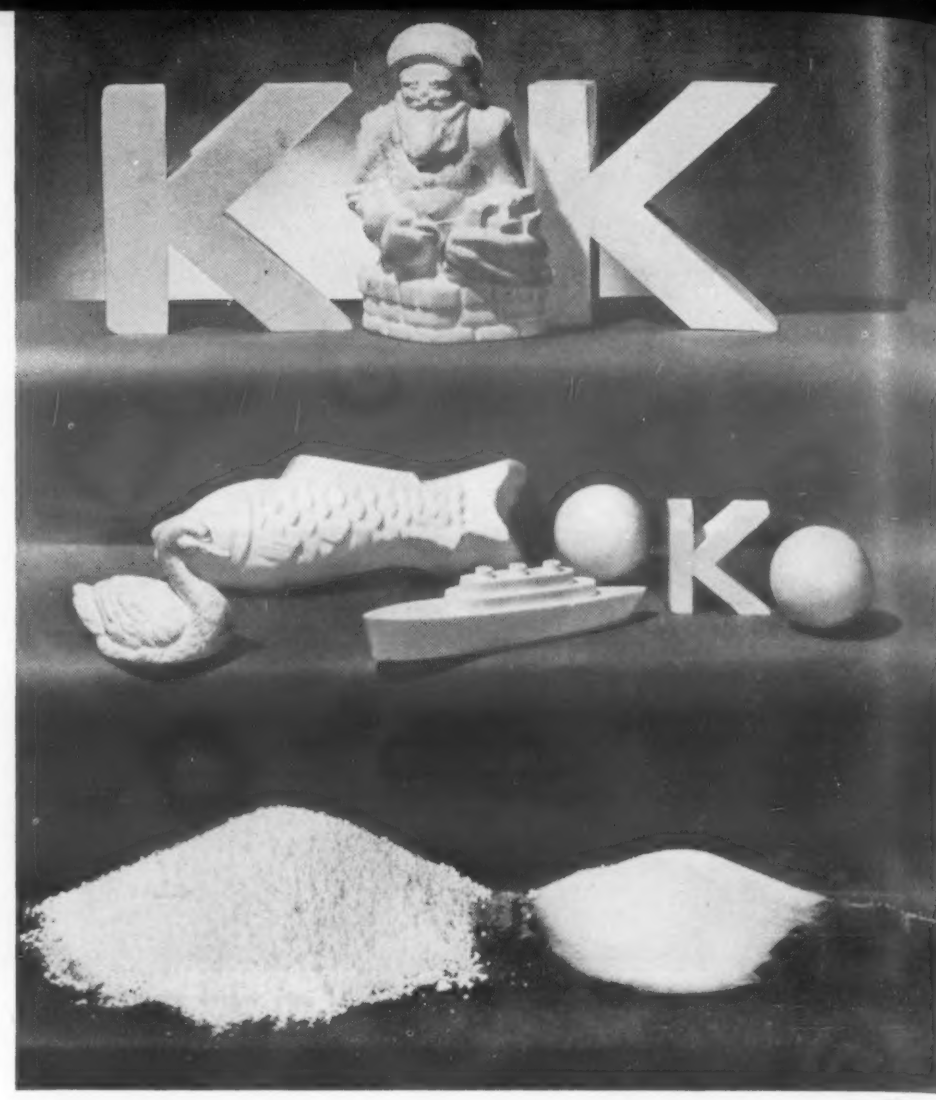
Adhesives containing non-solvents for polystyrene, such as water and the lower alcohols, are most satisfactory. These can be of the drying type (setting by evaporation of the solvent), or cold setting type that cure by chemical reaction. The former group includes the many water dispersed emulsion and latex types of adhesives, while the latter group includes phenol-formaldehyde, resorcinol-formaldehyde and urea-formaldehyde adhesives. Because of polystyrene foam's low vapor transmission characteristics, the drying type adhesives should only be used when bonding foam to porous materials such as wood.

Polystyrene foam can be easily worked with virtually all common woodworking tools. No special techniques are necessary since the foam can be sawed, planed and shaped in a manner similar to wood. Another technique, which has been quite successful with expanded thermoplastic materials, is the use of the resistance wire. In this method, best results are generally obtained if the wire is kept just below red heat. The method is most successful with low density material, i.e. 2-4 lb per cu ft. Higher density material cuts much more slowly and tends to fuse together on the cut surfaces.

Applications

Thermal Insulation—Polystyrene foam has low thermal conductivity, low water absorption, low water vapor permeability, and low density, all of which make it a good low temperature thermal insulation material. In addition, it can be molded to fit insulation areas such as the contours of refrigerator and freezer cabinets, trailer bodies, refrigerator cars, and low temperature industrial piping.

Polystyrene foam has high strength-to-weight ratio. Here a 2-oz rectangle of the plastic supports a 225-lb man.



At right, below, is a pile of polystyrene beads. Left are the beads after being expanded outside a mold. Above are various items produced in heated molds.

Sandwich Constructions — The toughness and resistance to fracture by impact, combined with good mechanical strength properties at its low density, make polystyrene foam of definite interest for various sandwich constructions. The ease with which it may be adhered to a variety of materials such as wood, fiberboards, laminated plastics, various metals, etc., allows fabrication of panels with the same techniques used with wood. Polystyrene foam remains dimensionally stable with changes in humidity, contrary to the behavior of wood, because of its low water absorption. Its low thermal conductivity imparts insulation ability to panels containing it.

Toys, Novelties, and Displays—The singular ability of this product to be expanded to desired shapes presents a new method for the production of various articles from expanded polystyrene. For the first time, the production of intricate and unusual shapes of expanded polystyrene by foaming, rather than pressing or cutting to shape is possible. The relatively smooth dense skin produced takes paint satisfactorily.

Buoyant Members—The low density, non-communicating cell structure, and low water absorption of polystyrene foam provide high buoyancy and the assurance that this buoyancy will be retained for long periods of time. These properties make it well suited to provide buoyancy in boats, rafts, buoys, and other marine equipment. Compartments can be completely filled by molding expandable polystyrene to desired shape.

Mechanical Properties of Polystyrene Foam

Density Lbs/cu ft	2	3	4	6	8	10
Tensile str, psi, ASTM D651-48	30 to 50	55 to 75	65 to 85	90 to 110	110 to 120	120 to 130
Compressive str, psi, 5% off-set ASTM C165-45	15 to 20	25 to 35	40 to 50	60 to 70	70 to 80	90 to 100
Flexural str, psi, ASTM D790-49T	Flexible	60 to 90	90 to 120	130 to 160	200 to 230	280 to 310
Impact str, (in.-lb/in.) unnotched (1 in. wide specimen) ASTM D256-47T	2.0 to 2.5	2.3 to 2.8	2.5 to 3.0	3.0 to 3.5	4.3 to 4.8	5.0 to 5.5

Test specimen size varied as necessary.
All tests conducted at 73 F.

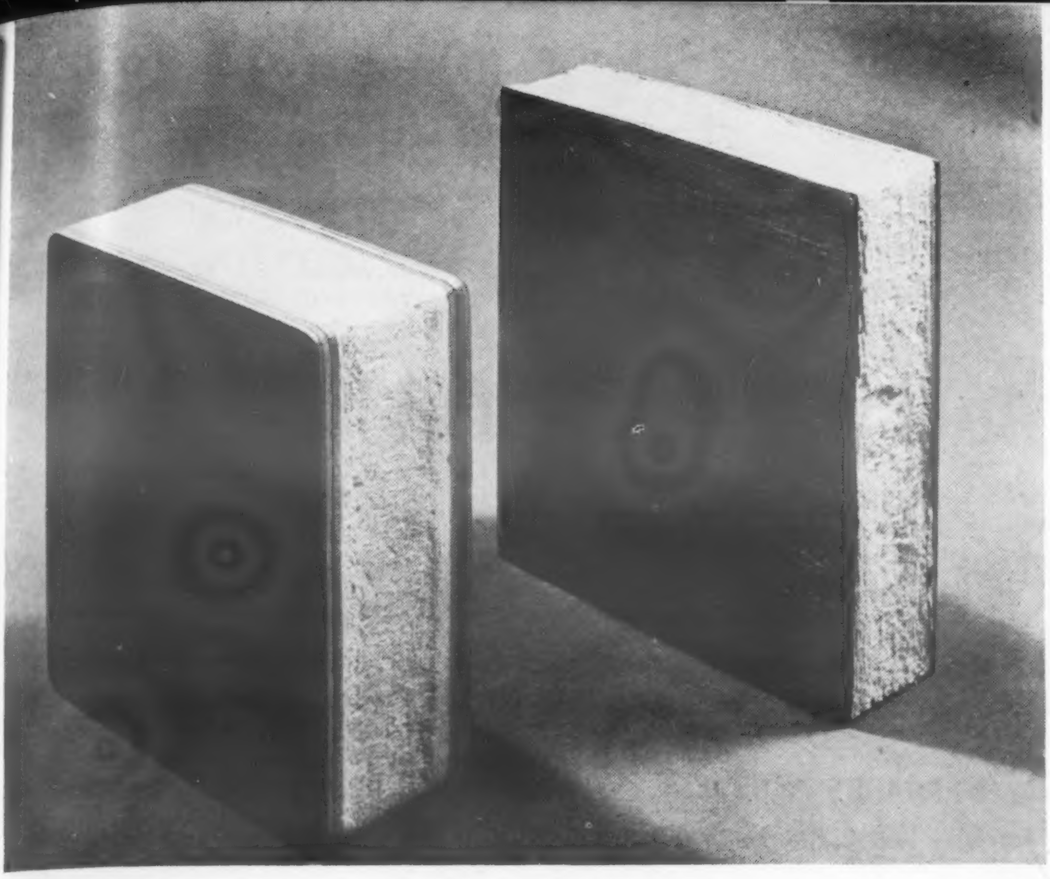
How To Mold It

The expandable polystyrene beads can be expanded to shape with readily controllable density in relatively inexpensive molds. Briefly the molding operation involves the following steps: 1) Charge a measured amount of beads to the mold. 2) Close the mold and apply heat (usually dry steam) until beads are expanded. 3) Remove source of heat and cool mold with cooling water. 4) Open mold and remove foamed article.

Expansion Techniques—The following three methods have been found to be best for expansion of polystyrene beads:

1. Direct introduction of dry steam into the mold cavity.
2. Steam heated molds.
3. Molds heated by hot air.

The choice of which method to use



One anticipated use of the new expandable plastic is for cores in sandwich materials. Here it serves as the core between plywood (left) and aluminum (right).

Mold Design

Brass, bronze, aluminum and steel are satisfactory mold materials, with brass and bronze being most desirable from the standpoint of ease of finishing, strength, dimensional stability and parting of the molded piece. Steel should be plated, or otherwise treated, to prevent rusting of the mold surfaces.

Molds can either be machined or cast from plaster models. Machine marks should be polished out of the mold. The finish of cast molds will probably be satisfactory if the plaster model is smooth. If a high gloss is wanted on the molded article, additional polishing will be necessary. Wall thickness should be at least 1/4 in. for most moldings. The mold should be designed in such a way that the molded piece can readily be removed from the mold on all sides. Successful moldings have been made using a 2 deg draft on all drawn surfaces.

For molding with direct steam, the mold should be so fabricated that steam can enter the mold cavity through holes (1/32 in. dia) located in the mold walls. The size, number and placement of these holes are important and vary with the size and shape of the article. For many designs, it has been found that 1 hole for each 2 sq in. of top surface area is satisfactory. Uniform distribution of holes over the area of the molded article is essential for complete expansion and uniformity of the molded shape. Placement of the holes in rows is generally satisfactory. With new designs, experimentation will undoubtedly be necessary to establish the proper number and placement of holes to obtain satisfactory expansion.

When molding with direct steam venting of steam and water from the mold cavity is essential for successful molding. To some extent, the inlet steam holes act as vent holes after expansion has started. Water is forced through these inlet holes into the steam chamber by the pressure exerted during expansion. Further, a perfect seal between the mold faces is not recommended. Elimination of water of condensation from the mold cavity also occurs by "weeping" at the parting line of the mold.

is governed by thickness of the article to be molded. For sections of foam intended to be one inch or greater in thickness, Method 1 is recommended. The rapid penetration of steam into the mold and the latent heat given up during condensation of the steam permit rapid molding cycles. Either Method 2 or Method 3 can be used for sections to be foamed that will be less than 1 in. in thickness. Steam heated molds give shorter expansion cycles than heating with hot air. When direct steam is used, it must be dry. Use of wet steam results in excessive water pick-up by the expanded piece, requiring a drying period.

Molding Pressures and Temperatures—Steam pressures for satisfactory expansion by all methods generally lie in the range of 10 to 30 psi. The pressure used is dictated by the size and/or shape of the article being molded. The internal pressure developed in the mold during expansion is a function of the density of the piece being molded. It falls in the range 10 to 50 psi for densities of 2 to 10 lb per cu ft. Temperatures of 230 to 275 F are used during expansion by all methods. If temperature exceeds 275 F, the expanded material will become too plastic and collapse.

Molding Cycles—Expansion cycles vary with the method of expansion used, density, and size of the molded article. With steam introduced directly into the mold the expansion time may be as short as 10 sec for small pices, and as long as 3 min for sections 12 in. thick.

With molds heated by steam or by hot air, the expansion cycle depends on the thickness of the piece. For 1-in. thick articles, this may be as long as 20 min. with hot air and 10 min. with steam. Thinner sections require shorter times.

The molded shape must be cooled to below 104 F before it is removed from the mold. Expansion will continue if the foamed article is removed without cooling. Cooling time varies with mold wall thickness, thickness of the molded article and density. It can be as short as 1-2 min for small articles to 10-15 min for pieces 12 in. thick. Shock cooling should be avoided as it will cause immediate shrinkage and partial collapse of the piece. In general, high density pieces (4 lb/cu ft and higher) can be cooled without collapse at a faster rate than can pieces at a density of 2 lb per cu ft.

Silicone greases have been found to be satisfactory mold release agents for easy removal of the foamed article.

How the Government Buys

Part 3 • Military and Federal Standards

by MARGARET P. HASKIN,

Purchase Specifications and Standards Branch, Bureau of Ships, Navy Department

Government Standards like industry standards help eliminate waste, improve efficiency of operations, and facilitate interchangeability and replacement. This concluding article explains the various types of Federal and Military Standards and how they can be used to advantage.

● THE VALUE OF industry standards has been proven many times. Since Government Standards are actually the result of coordinated efforts of government activities and industry, the same benefits should be realized from them as have been realized from industry standards.

Some Definitions

Standards. — Documents, which may be used in invitations for bids, proposals and contracts, that establish engineering and technical limitations and applications for materials, processes, methods, designs, drafting room and other engineering practices or any related criteria deemed essential to achieve the highest practical degree of uniformity in materials or products, or interchangeability of parts used in those products.

Federal Standards. — To cover engineering and related practices and shall be mandatory for use by all Federal activities.

Military Standards.—To cover engineering and related practices and shall be mandatory for use by all Military activities.

Federal Standards

Federal Standards are developed to achieve the following objectives: (a) reduction in number of sizes, types, and grades of items used by Federal agencies, (b) reduction in types of packaging, consistant with economy and efficiency of operations, (c) uniformity of dimensions or other characteristics which facilitate interchangeability and replacement, (d) uniformity in the practices and processes required in the manufacture, preservation, packaging, packing, inspection, and acceptance of items to achieve maximum economy, (e) uniform terminology and definition of technical, engineering, and supply practices and processes.

Federal Standards are identified numerically; for example:

Fed. Std. No. 5—Standard Guides for Preparation of Item Descriptions by Government Suppliers.

Military Standards

Military Standards are issued by the Military Departments to establish limitations applying to items, materials, processes, methods, designs, and engineering practices. Military Standards are issued in two formats

as follows:

Book Form (MIL-STD). Military Book Form Standards cover engineering practices, charts, categories of dimensional and functional details, graphs, formulas and lists. These standards utilize textual or graphical presentation or both, and may be issued in unit page form when only one sheet is required. They are identified by the symbol "MIL" followed by a hyphen and assigned arabic numerals. Example:

- MIL-STD-101—Color code for compressed gas cylinders and pipelines
- MIL-STD-105—Sampling procedures and tables for inspection by attributes.

Sheet Form (MS)—Military Sheet Form Standards cover physical items and design features. They are limited to those dimensional and functional details required to insure interchangeability. Military Sheet Form Standards utilize graphical presentation combined with tabular presentation and notes if necessary. They are identified by the symbol "MS" followed by assigned arabic numerals. Examples:

- MS 13928—Expander, piston ring, oil
- MS 15000 — Fittings, lubrication (hydraulic) acceptable tip designs.

Coordinated and Limited Coordination Standards—Military Standards are further divided administratively into "coordinated" standards and "limited coordination" standards. "Coordinated" standards are those covering items or areas of use common to more than one department which have been concurred in by all interested activities. "Limited coordination" standards are those issued by a single department or activity covering an area unique to that department or activity, or to satisfy an immediate need for a standard.

Limited coordination standards carry a suffix after the regular symbol to identify the issuing activity. Example:

- MIL-STD-213 (Navy) Designation system for gas turbine engines, Marine
- MS 15250—Fuse, cartridge, ferrule contact, style F61.

Changes to Military Standards—Changes to Military Standards are made either by complete revisions or by means of revised pages. Revisions are identified by a capital letter and the superseding data. Revised pages carry the revision date.

Use of Military Standards

Military Book Form Standards include statements covering the purpose, application and effective date. For example, MIL-STD-2—Drawing Sizes, states under "Scope" that the drawing sizes covered therein shall be used by the Departments of the Army, Navy and Air Force in the preparation of drawings. MIL-STD-214—Amplifiers, Audio Frequency, General Purpose, states that it covers the types and characteristics of general purpose audio frequency amplifiers to be used by the Military Services.

Although the definition and intent is the same for the two forms of Military Standards, Military Sheet Form Standards have been used to cover other than standard items due, largely, to the lack of a series of Military documents such as standard drawings, covering items which need to be so described and yet may not be established as standard. In addition, the present format for Sheet Form Standards does not provide for any statement of purpose, application, intent or implementation. Since their use is governed by the documents in which they are referenced, e.g., specifications or procurement documents, the original intent of a Military Standard is often lost.

The system of Military Standards, particularly Sheet Form Standards, is relatively new and requires clarification and changes in administration. The Standardization Division of the Office of the Assistant Secretary of Defense (Supply and Logistics) is now modifying the system to correct the deficiencies. In the meantime, to clarify their use and significance, Military Sheet Form Standards prepared by the Bureau of Ships will include a statement of purpose and application.

Obtaining Copies of Standards

Volumes II, III, and IV of the Military Index list the Federal and Military Standards approved for use by a particular Department. Copies of individual standards used by the Army, the Navy and the Air Force, may be obtained as indicated in the foreward of the applicable volume of the Index. Copies of the three volumes may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

A complete list of Federal Standards will be found in the "Index of Federal Specifications and Standards" issued by the General Services Administration, Federal Supply Service. Copies of this Index may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Copies of individual Federal Standards may be obtained at the prices indicated in the Index, upon application accompanied by check, money order, cash, or Government Printing Office coupons, to the Business Service Center, General Services Administration, Regional Office Building, Seventh and D Streets, S.W., Washington 25, D. C. This office will also honor deposit account numbers issued by the Government Printing Office.

Since Government Standards are continually being changed, it is the practice to furnish only the latest issue. Copies of superseded or cancelled standards are issued only when specifically required by an invitation for bid or an existing contact. In such cases, where a specific issue of a standard is required, the request should so state. Whenever copies of standards are requested, the title as well as the number should be given.

Suffixes Used for Identification of Limited Coordination Standards:

	Army
CmlC	—Chemical Corps
CE	—Corps of Engineers
Med	—Army Medical Service
Ord	—Ordnance Corps
QMC	—Quartermaster Corps
SigC	—Signal Corps
TC	—Transportation Corps
	Navy
NAVY	—Department of the Navy
Aer	—Bureau of Aeronautics
MC	—Marine Corps
BuMed	—Bureau of Medicine and Surgery
NOrd	—Bureau of Ordnance
Pers	—Bureau of Personnel
Ships	—Bureau of Ships
S&A	—Bureau of Supplies and Accounts
Docks	—Bureau of Yards and Docks
	Air Force
USAF	—Department of the Air Force
	Joint
ASG	—Aeronautical Standards Group

Materials at Work

Here is materials engineering in action . . .

New materials in their intended uses . . .

Older, basic materials in new applications . . .

Plastic Bag "Sandwich" Lines Steel Tanks The recent development of a method of welding Kel-F, one of the fluorocarbon plastics, has led to the design of a custom-built envelope of the material to provide corrosion-resistant linings for steel tanks.

A vinyl or polyethylene envelope is first slipped over an inflated form, then the Kel-F bag fits over that, and the whole is then covered with another vinyl bag. These vinyl envelopes are installed to protect the relatively thin Kel-F membrane from mechanical damage during installation. The complete assembly is then

fitted into the steel tank, and supported by a structure of acid brick masonry.

This method of lining tanks has been developed by U.S. Stoneware, and is said to provide almost universal corrosion resistance over a wide range of temperatures.

Giant Chromium-Molybdenum Die Will Reduce Tubing

Pictured on a vertical boring mill is an 8400 lb die section, 50 in. in dia, said to be the largest of this type ever constructed. The die will be used by the Tube Reducing Corp., to expand their line of cold finished compression-formed tubing to 17 in. o.d.

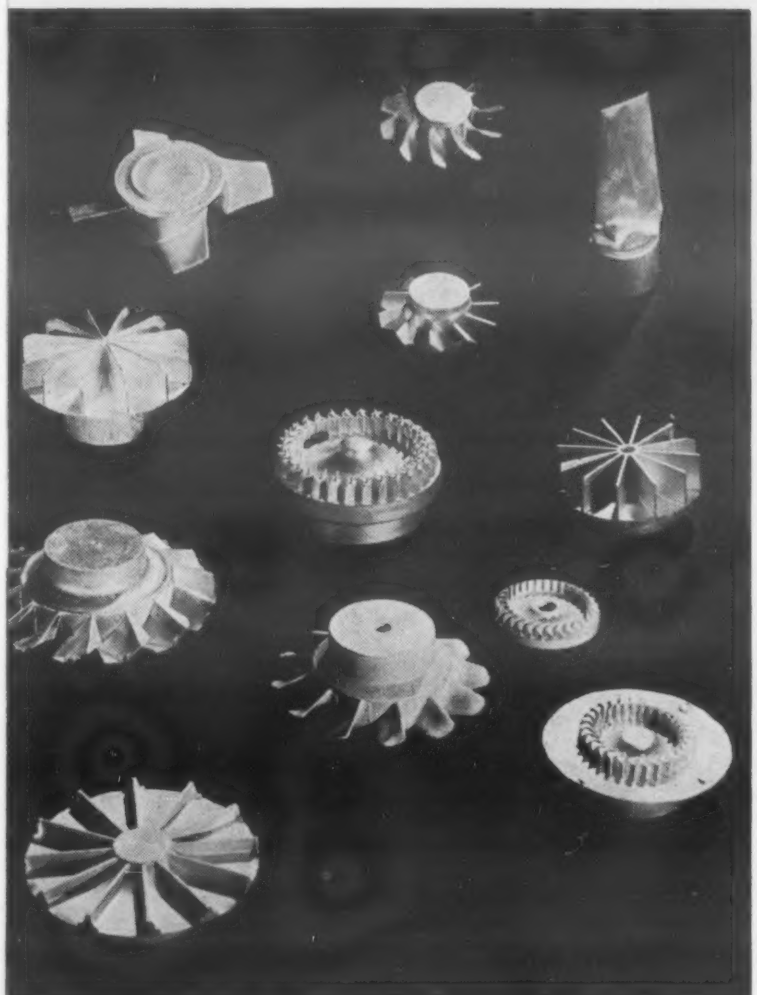
The die was forged from a chromium-molybdenum roll steel ingot weighing 38,600 lb; the finished die has a 31 in. face width.

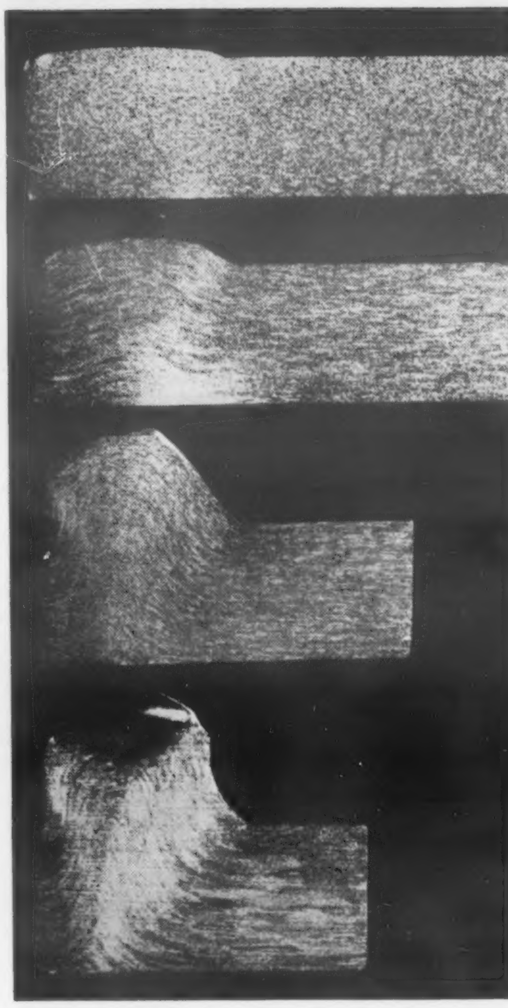
Cushions of Stainless Steel

One of the latest uses reported for stainless steel wire made by Fort Wayne Metals is in the production of shock absorbers for delicate electronic equipment installed in aircraft, tanks and other locations where high shock and vibration are common.

Developed by Robinson Aviation, the new cushioning element consists of specially hardened stainless steel wire first knitted into a sleevelike mesh, then flattened, rolled and compressed to the proper density. The cylindrical roll is enclosed in a single sleeve of fine annealed wire mesh and inserted in a stainless steel coil spring in the finished shock absorber unit.

Stoneware, ost univer- er a wide





These are Aluminum Extrusions

These aluminum wheels and fans with diameters ranging from 2 to 4.5 in. and weights of 2 oz to 1½ lb are hot extruded to finished sizes and contours by the Phoenix Div. of The Garrett Corp.

The parts are produced on a specially constructed 1100 ton press, holding tolerances of 0.001. The wheels are used in air cooling, refrigeration and ram air turbines.

Alloys such as 14S aluminum with tensile strengths of 60,000 psi are used, the extrusion process adding increased, consistent strength the length of the blades.

The cross sectional view shows how the grain flow of a fan changes direction with extrusion. From the axial flow shown at the top to the finished radial flow at the bottom, considerable strength has been added to the blades which in the finished product may spin at speeds up to 100,000 rpm.

Rubber Springs Give Bounce to Buses

A rubber spring that looks like a large steel pipe rather than a conventional bus spring is being used on over 740 new buses of the Chicago Transit Authority.

The so-called Torsilastic spring, manufactured by the B. F. Goodrich Co., consists of a metal shell and central shaft, with the space between shell and shaft filled with rubber bonded to the metals. Either the shaft or the shell is held stationary while the other is partly rotated by a torque arm. The spring action is accomplished by the twisting, "wind-up" movement in the rubber.

Less than 100 lbs of rubber are needed to suspend an entire bus chassis weighing 20,000 lbs. The spring is said to eliminate the metal-to-metal path for vibration and road noises found in other suspension systems.

According to reports, 5900 buses equipped with the rubber springs and operating in cities from coast to coast have traveled over one billion operating miles.

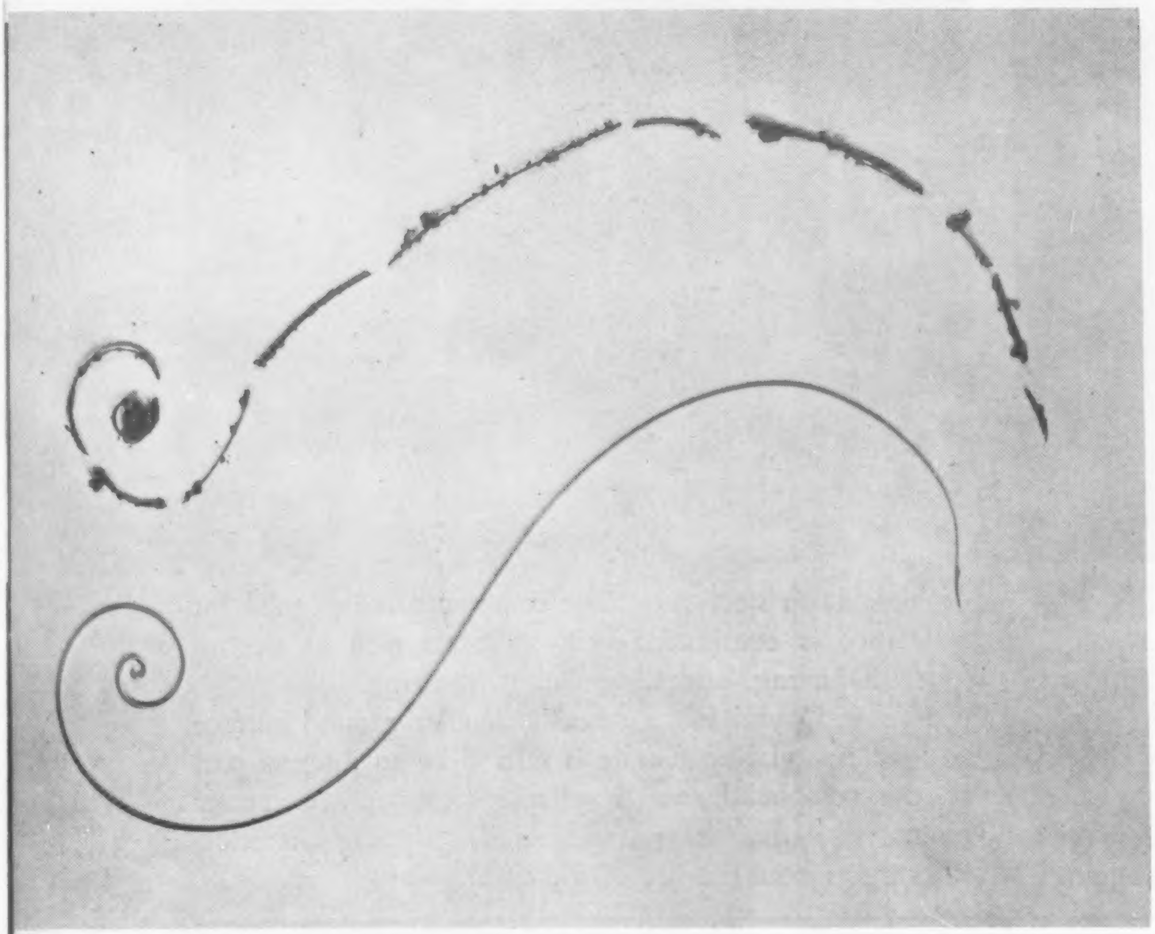
New Compound Cuts "Fogging" in Steel Strip Production After two hours service the conventional rubber-covered tension roll at left developed the shiny band with cracks and corrugations, while the roll at right covered with the new compound, shows no sign of deterioration after six months of service.

Produced by B. F. Goodrich, the Strip-Grip compound is said to drastically reduce slippage and surface "fogging" of high finish steel strip. The compound is designed for rolls used in continuous strip processes such as electrolytic tin plating, annealing and galvanizing.

The compound has a smooth, regular ground surface and the non-glazing feature is said to be an integral part of the compound, not a surface treatment. Company reports state that the roll retains its gripping characteristics throughout the life of the cover.

Largest Fully-Molded Rubber Part? Believed to be the world's largest fully-molded rubber part, this 1120-lb pad will be installed on a press used to form aircraft parts.

Measuring 5 ft wide by 13 ft long, the pad was made of a specially-compounded rubber by Goodyear Tire & Rubber Co. The pad is designed to operate under pressures of around 10,000 psi in a direct action hydraulic press.



Alloy Spring Beats Rust The cobalt-base spring alloy, Elgiloy, has again become available on the commercial market. The Elgiloy spring (bottom) and the carbon steel spring (top) were both exposed to 100% humidity for 18 days. After this time, the carbon steel spring had disintegrated into small brittle sections encrusted with rust, while the Elgiloy spring was rust-free.

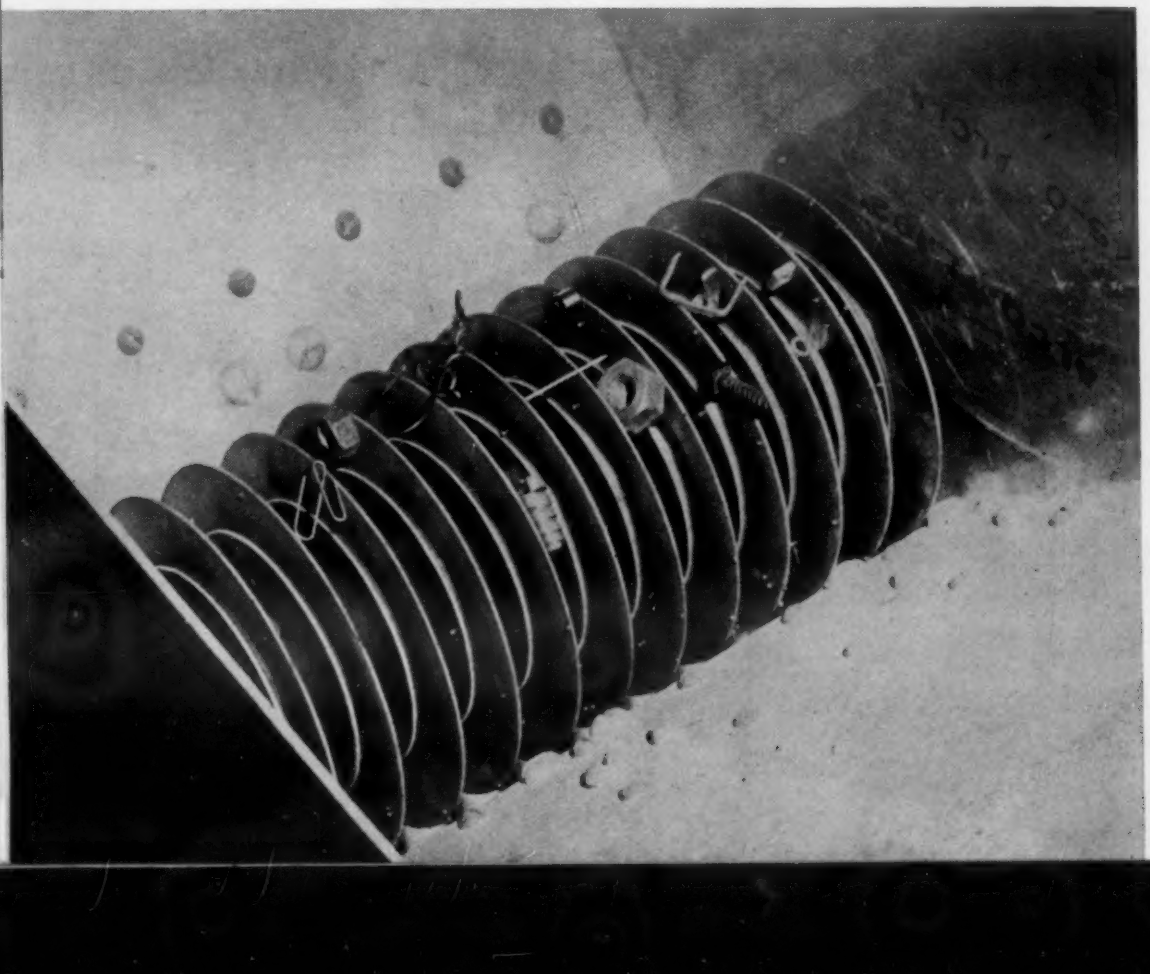
The alloy, composed of cobalt (40%), chromium (20%) and nickel (15%), has high hardness, toughness, tensile strength, set and fatigue resistance, and is nonmagnetic as well as being corrosion resistant.

Applications for the alloy are said to include fountain pen nibs, watch springs, toaster pop-up mechanisms, flapper valves, surgical and dental equipment, drawing instruments camera parts wrist watch bands and switch components as well as other forms of springs.

Textured Aluminum Lightens Sportsman's Boat The increased strength provided by a three-dimensional pattern in aluminum sheet stock allows the reduction in gage from 0.032 to 0.025 in. in this light-weight sportsman's boat.

Though the heavier gage material is still used on the bottom of the hull to protect it from rocky shores, the reduction in thickness of the other parts reduces the overall weight of the boat for ease of transportation and handling.

Use of the patterned aluminum, produced by Rigidized Metals Corp., is also said to improve the appearance of the boat.



Magnet Keeps Plastic Metal-Free This series of 6-in. dia circular magnetic disks, spaced at 1-in. intervals around a magnetic core provides an automatic method of removing any tramp metal from plastic pellets produced by Apex Tire & Rubber Co.

The permanent magnets, manufactured by Eriez Mfg. Co., eliminate the need for wiring and electrical sources and are installed in the throat of the hopper through which the free-flowing plastic material passes. The magnets are freed of metal by lifting them from the hopper and wiping them clean with a cloth.

Materials for High Temperature Service

by H. R. CLAUSER, Managing Editor, Materials & Methods

MATERIALS & METHODS
Manual No. 104

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.

APRIL 1954

Here is a broad and general survey of the materials commonly used at temperatures above 300 F. Although not an exhaustive study, it will acquaint the engineer with the wide range of materials from which he can select the ones to meet his particular needs. Among the materials covered are:

- ***Superalloys***
- ***Irons and Steels***
- ***Light Metals***
- ***Ceramics and Cermets***
- ***Plastics***
- ***Copper and Copper Alloys***

The Selection Problem

● IN THE DESIGN and production of an increasing number of products, engineers and designers are confronted with the problem of selecting materials to meet high temperature service conditions. The purpose of this manual is to aid in solving this selection problem by giving a broad picture of the materials generally used in high temperature applications. The purpose is not to present detailed information or recommendations of what materials to use for specific applications, but rather to acquaint the engineer with the wide range of materials available from which to select the one to meet his particular needs.

The materials covered here are those used at temperatures above about 300 F. They include a large number of ferrous and nonferrous metals, ceramics, cermets and some plastics. Many coatings are also applicable to high temperature service, but due to space limitations, they cannot be covered here. Nor are refractory materials for such applications as furnace linings included.

Before making a final choice of materials, the advice of a reliable producer or producers of heat resistant materials should be sought. Their knowledge and their experience in handling similar problems in the past can often save considerable time and expense. The producer should be given complete information about the requirements of the part and under what conditions it will operate so that he can base his recommendation on all the facts.

Following is a list of most, but not necessarily all, of the possible conditions that may have to be considered in the selection of a material for any given high temperature application.

1. Temperature of operation.
2. Possible maximum temperature.
3. Temperature cycling.
    a. Range of temperature cycling.
    b. Frequency of temperature cycling.
4. Thermal shock conditions.
5. Type and size of load.
6. Manner of support.
7. Type of atmosphere or other corrosive conditions.
8. Abrasive or wear conditions.
9. Continuous or intermittent operation.
10. Expected life.
11. Cost.
12. Ease of replacement.
13. Fabricating, welding or forming.

The significant properties that must be considered in selecting a material to meet the above operating conditions are discussed below.

High Temperature Strength

It is a well-known fact that strength and, therefore, load carrying ability of materials decreases as temperature increases. It is also well-known that strength properties at elevated temperature must be considered differently than at room temperature.

Most materials generally pass through three stages as temperature increases. At room temperature and up to a certain point, they are entirely elastic. They then go through a stage in which they are both elastic and plastic. And finally, they are completely plastic. The temperatures at which these stages occur are not the same for all materials.

At high temperatures, where metals under stress no longer behave elastically, but are subject to slow plastic deformation, time becomes a critical factor and conventional tensile test values cannot be used. The problem becomes one of determining the load which at a given temperature will not produce more than a certain allowable degree of deformation or will not rupture in a given time period.

Creep Strength—The matter of evaluating strength at temperatures where plastic characteristics predominate is controversial. But at present, creep test properties are generally considered one of the most reliable indications of hot strength under relatively constant temperature conditions.

Creep data—more specifically, the limiting creep stress to produce a selected minimum rate of creep—is frequently the basis for calculating allowable design stresses. It is usually expressed in terms of percent deformation per 1000 hr. The minimum creep rates selected for comparison and design vary considerably depending upon the application. But on the basis of experience, rates of 0.01, 0.10 and 1% per 1000 hr are most commonly used.

Stress-Rupture—Stress-rupture data are often valuable in evaluating the strength of high temperature materials and in the establishment of allowable design stresses.

The principal object of a stress-rupture test is to determine the time-to-fracture under a constant load at a constant temperature. It therefore gives a rough approximation of the life expectancy of the alloy under relatively constant temperature conditions. The results are also useful in comparing alloys for service in which severity of load or overloading might produce failure in a relatively short time.

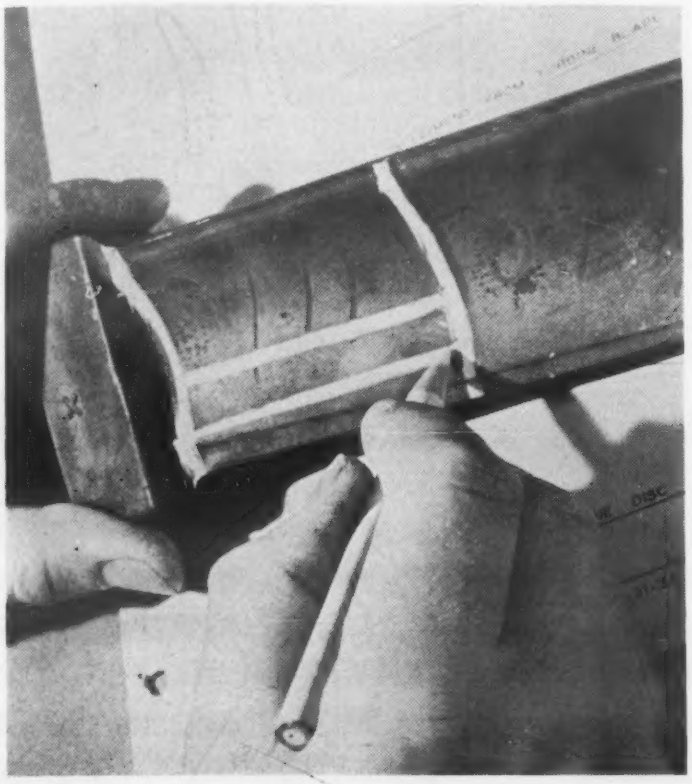
Ductility—Accurate comparison of hot ductility of heat resistant materials is difficult since there is no one generally accepted reference test. Total elongation on both creep and stress-rupture tests are often used as criteria. Also, elongation values in short time high temperature tensile tests are commonly used in specifications as an indication of high temperature ductility.

Short Time Tensile Properties—Short time hot tensile tests in which the test specimen is held at the test temperature for one hour and then pulled, cannot be relied upon to indicate how the materials will behave in service. The values obtained are as much as five or six times the limiting creep stress values and, therefore, greatly over-evaluate load carrying ability over long periods. Nevertheless, short time tensile tests can be helpful in evaluating resistance to momentary overloads, and are included in some specifications.

Allowable Design Stresses—Where service experience is available, allowable design stresses are determined on the basis of the experience of both the user and producer. And their decision depends upon the part and service conditions. A frequently used

One Way of Measuring High Temperature Strength

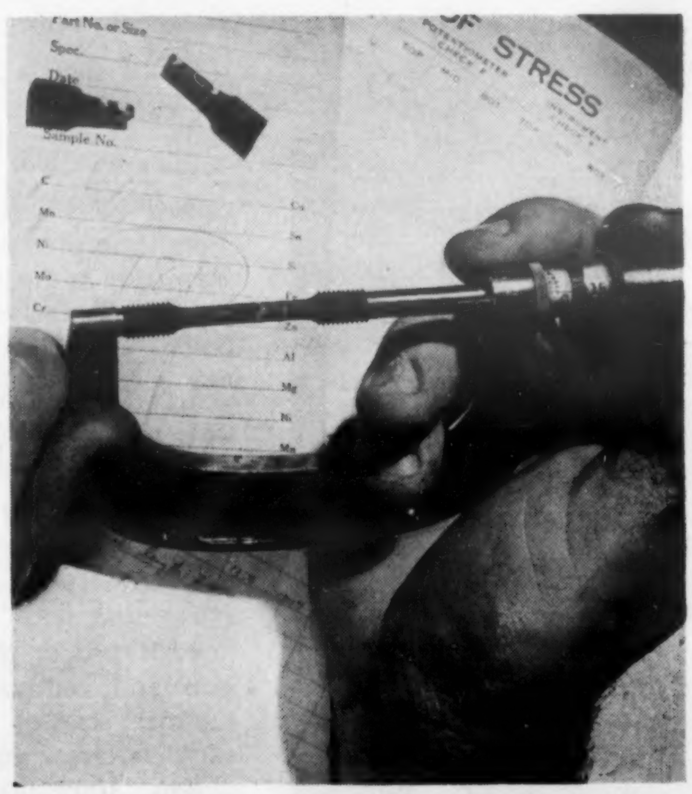
Stress-rupture tests are used at Pratt & Whitney as part of their quality control to check on the quality of turbine disks and blades going into their jet engines. Below are the principal steps in the tests.



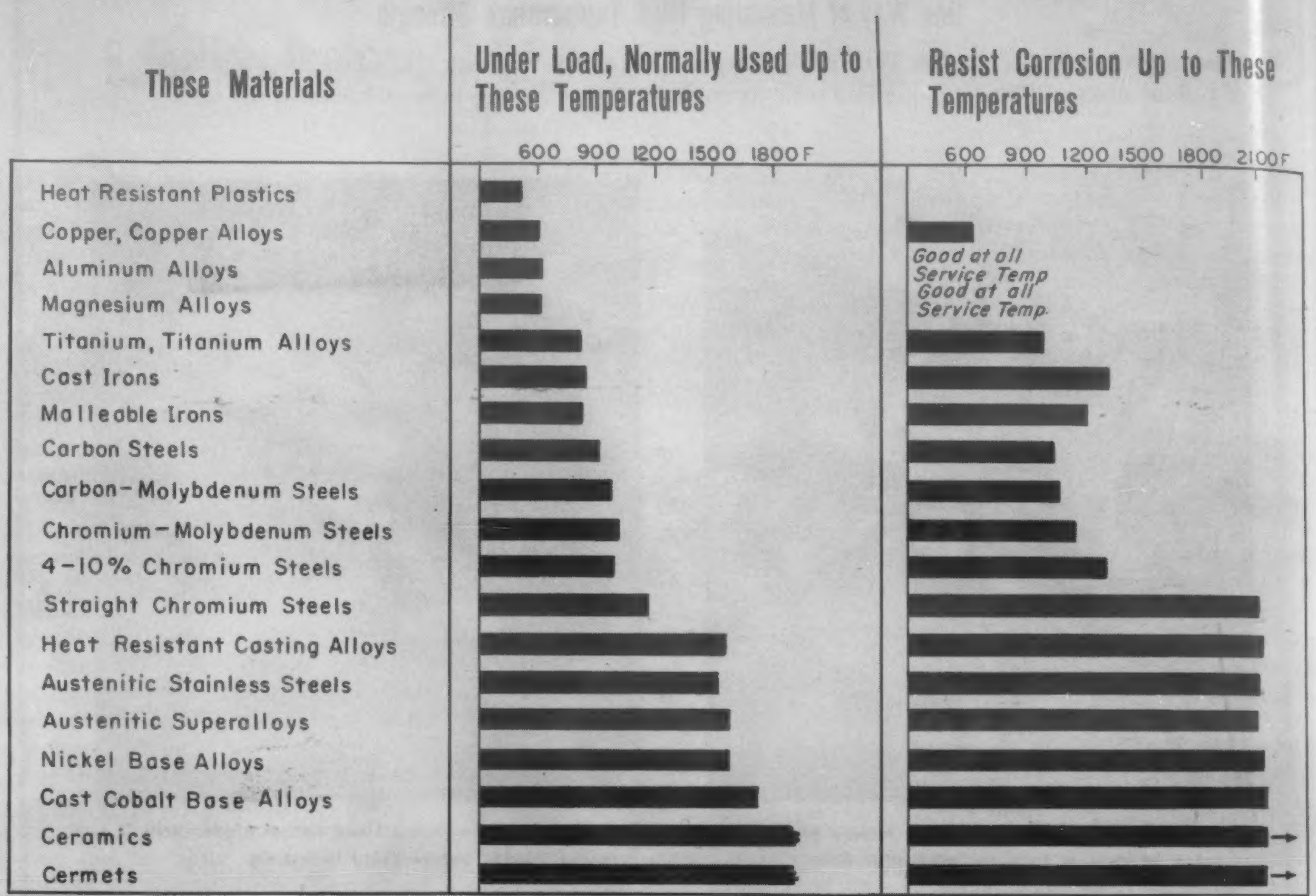
1 A small area is marked off on a turbine blade blank taken at random from the production line.

2 A test specimen is machined out of blade. Here it is being checked before going to test rig.

3 Rupture tests are run in small electric furnace at temperatures from 1200 to 1500 F. Here test rig is given final adjustment.



4 After rupture, test piece is fitted together and elongation measured.



NOTE: This chart gives only an approximate indication of high temperature service performance. Values vary widely within each group of materials depending on composition, treatment, method of production and service conditions.

maximum allowable design stress is 50 to 60% of the stress required for rupture in the life of the part. The stress selected is then compared with the allowable deformation in that time. This rule only applies where temperature is constant and where changes in stress are infrequent and not excessive. Where cyclic heating is involved, design stresses must be much lower—by a factor of at least two or three.

Thermal Fatigue—In many high temperature applications intermittent or widely fluctuating temperatures (cyclic heating) are encountered. Thermal fatigue failure involves cracking characteristically caused by very rapid heating and cooling cycles. Such failures are the result of many reversals of thermal stresses in the part as contrasted to common mechanical fatigue failures, which are caused by externally applied loads. Very little precise thermal fatigue information is available on which comparison of the various alloys can be based, and no standard test as yet has been adopted.

Thermal Expansion and Distortion

Closely related to thermal fatigue is the problem of thermal expansion and distortion and warping. All metals expand with increasing temperature. If proper provision for expansion and contraction is not made, thermal stresses set up can cause early failures. In high temperature design, allowances for dimensional variations must be many times as great as those encountered in structures at normal temperatures. The thermal coefficients of expansion aid the designer by giving an indication of how much expansion must be allowed for.

Surface and Structural Stability

Surface Stability—In the selection of high temperature materials, consideration of surface stability is of paramount importance. Equipment for high temperature service frequently operates under oxidizing or reducing conditions or in contact with corrosive gases or chemicals. Elevated temperatures generally accelerate scaling and action of corrodents. When the corrosive attack is severe enough, metal thickness may be reduced to the point where it can no longer withstand the imposed stresses.

It is dangerous to generalize about oxidation and corrosion resistance. Very slight changes in alloy content

or in service conditions can completely change the behavior in what is otherwise an identical situation. The only completely safe procedure is to test the material under truly representative service conditions.

Structural Stability—At elevated temperatures, materials, in general, are not as structurally stable as at normal temperatures. However, it is desirable that they change as little as possible under the given service conditions. Lack of structural stability can involve carbide precipitation, spherodization, graphitization, sigma-phase formation, temper embrittlement, carburization, etc.

Other Properties

Besides the above properties, there are others that may be important depending on the particular application. These include high temperature wear resistance, thermal conductivity, thermal shock resistance, room temperature properties, weldability, hot working characteristics and other fabricating characteristics.

Data available on some of the high temperature properties are not too complete. And where data are available from several sources, they often do not agree. Although comprehensive investigations are underway, there are at present, many gaps and therefore evaluation of materials based on test property data must be done cautiously. Usually the best method of choosing high temperature materials is to combine a consideration of field and service experience with available test data.

Plastics

While many plastics can be used at temperatures up to around 200 and 250 F, relatively few are useful much above 300 F. The discussion here will be limited largely to those generally applicable for uses to withstand temperatures of above 300 F.

The fluorocarbon plastics commonly known as Teflon, Fluorothene and Kel-F, are thermoplastic materials which have considerably broadened the high temperature service range. Teflon withstands continuous service temperatures up to 500 F. Kel-F is useful up to about 400 F. Silicone rubber has also been found suitable in this temperature range.

These materials are finding increasing use for gaskets and sealants, for insulation in electric motors, and for other applications where high temperature resistance is needed. Because of their relatively low strength their use is largely limited to non-structural applications.

For high temperature structural uses, heat resistant polyesters, silicones and phenolics show most promise. Heat resistant polyesters and silicones are thermosetting type plastics and also can be used up to about 500 F. The high temperature properties of polyesters deteriorate during prolonged exposure. The silicones, however, maintain their properties even under prolonged exposures, but do not have initial high strength and stiffness.

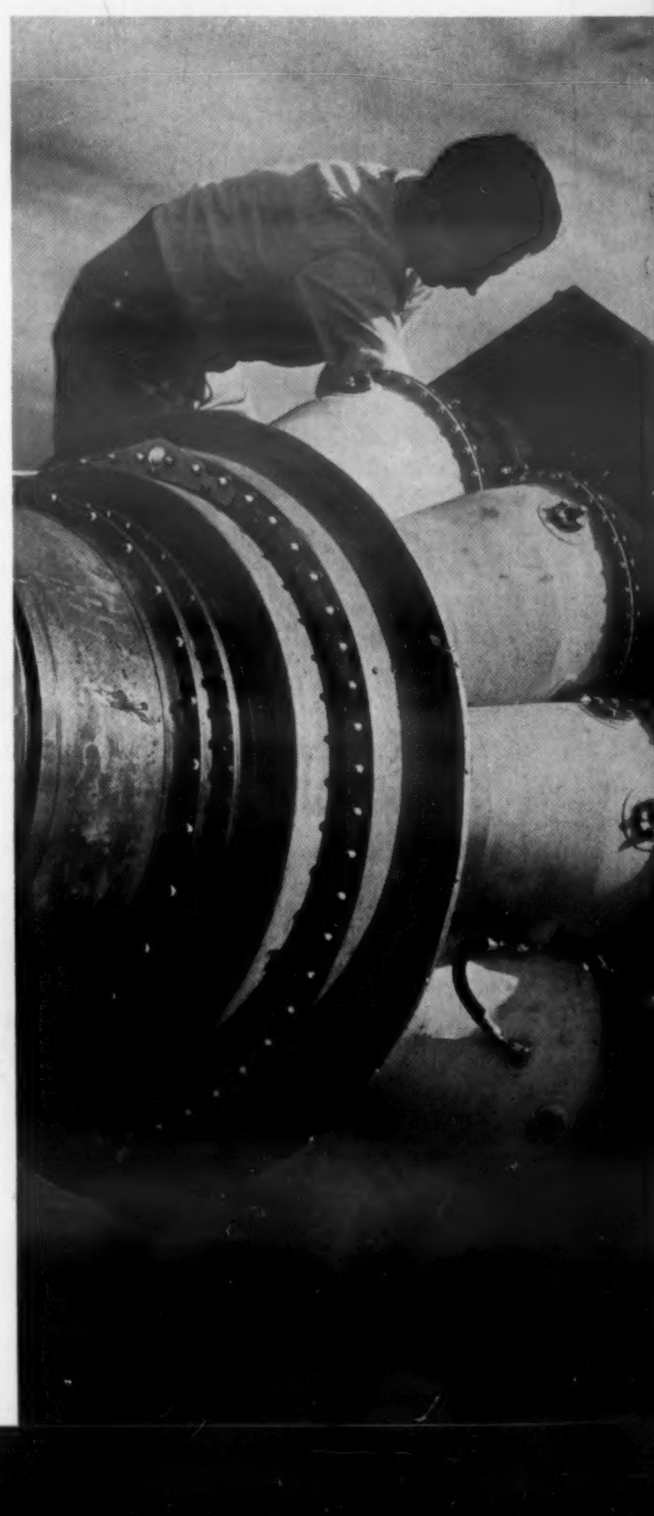
Glass fiber reinforced polyesters and silicones are being used for laminated structural aircraft components. These applications involve glass fiber faced sandwiches with cores of either foam plastic, honeycomb, or glass fiber channels.

Phenolic-glass laminates, with a recently developed high temperature phenolic, perform satisfactorily up to 500 F. At this temperature they are probably the highest strength plastic combinations thus far developed. Currently the materials are being evaluated for aircraft and guided missiles, and for high temperature electrical insulation. They have already been used in a compressor stator case subject to a prolonged temperature of 500 F and for jet engine compressor blades.

Properties of Some Heat Resistant Plastics

Name	Flexural Strength, 1000 psi			Max. Service Temp. F	Uses
	Room Temp.	300 F	500 F		
Phenolic Laminate (CTL91LD)	53	52	42	500	Structural
Polyester Laminate (TAC Mod.)	—	41	23	500	Structural
Silicon Laminate	30	17	14	500	Structural
Teflon	1.6	—	—	500	Gaskets, motor insulation.
Kel-F	8.2	—	—	400	Gaskets, motor insulation.

Rapid advances in jet engine design are requiring materials that will withstand higher temperatures than ever before.



Copper and Copper Alloys

The usefulness of commercial coppers at moderately elevated temperatures depends to a large extent on the softening point which varies with the type of copper and the degree of cold work. Tough pitch copper has the lowest softening point and silver bearing types have the highest. Additions of arsenic and phosphorous raise the recrystallization temperature, although the effect of phosphorous is not as great as that of silver or arsenic.

Creep strength of copper is also affected by composition and degree of cold work. Thus, electrolytic tough pitch and oxygen-free copper have lowest creep strengths, followed by phosphorized copper. Silver bearing and arsenical coppers have the highest. Silver bearing and arsenical coppers are therefore used more widely than the others for high temperature service. The resistance to oxidation and scaling of commercial coppers is such that most of them are seldom used at temperatures above 500 F.

Of the copper alloys, the aluminum bronzes are probably most widely used for elevated temperature applications. They have excellent resistance to oxidation and scaling. This resistance increases with aluminum content. They retain most of their strength up to 300 to 400 F. But beyond 600 to 750 F, strength decreases rapidly.

Other copper base alloys that find considerable service above 300 F are the cupro-nickels. These materials have good creep strength up to 600 or 700 F. Their corrosion resistance and resistance to oxidation and scaling is also adequate for use in this temperature range. Also, these alloys with small amounts of cold working do not soften at 500 F for periods of time in excess of 6000 hr.

High Temperature Properties of Copper and Copper Alloys

Designation	Coppers	Brasses*	Bronzes	Cupro Nickel
Form and Condition	Wrought, Annealed	Wrought, Annealed	Wrought, Annealed	Wrought, WQ and Aged
General Composition	Commercially pure or alloyed with not more than 1% other elements.	Cu-Zn alloy plus small quantities of other metals.	Cu-Al, Cu-Si, Cu-Sn, alloys.	Cu-Ni alloy (10-30% Ni).
Creep Strength (1000 psi) at:	0.01%/1000 hr	0.01%/1000 hr	0.01%/1000 hr	0.01%/1000 hr
300 F	3–8	9–19	14–23	25–40
400 F	1.5–5.0	2–11	5–10	15–30
500 F	0.4–2.6	0.3–2.3	2–5	8–30
Thermal Expansion (in/in./°F x 10^{-6}) 68-570 F	9.8	10–11	9.0–10.2	9.0–9.5
Applications	Seldom used above 500 F. Boiler tubes, heat exchanger tubes.	Seldom used above 500 F. Heat exchangers, tube sheets and tubes.	Seldom used above 500 F. High temp gears and bearings, heat exchangers, engine cylinder heads and valve sleeves.	Can be used up to 600 or 700 F. Heat exchangers, tube sheets and tubes, feed water heaters.

* *Does not include leaded brasses.*
All properties are approximate. Creep values vary widely depending on grain size and composition.

The Light Metals

Aluminum Alloys

Several aluminum alloys retain a relatively large part of their room temperature strength and hardness at temperatures up to around 600 F, and for this reason find use in internal combustion engines for such parts as pistons and cylinder heads.

Both cast and wrought alloys are used in engine parts. Their principal advantages are light weight, good thermal conductivity, and excellent surface stability. The most widely used casting alloys are aluminum-coppers containing 10 to 15% copper; aluminum-copper-nickel-magnesium alloys containing about 4 copper, 1.5 magnesium, 1.0 to 2.0% nickel; and aluminum-silicon alloys containing 12 to 20% silicon.

Of the wrought alloys 18S, 24S and 32S are used as forgings for piston rods. The minor additions of nickel in 18S and 32S make these exceptionally resistant to corrosion at elevated temperatures.

Aluminum alloys such as 24S and 75S in sheet form generally retain most of their short time tensile properties up to 250 F. Above this temperature, strength tends to decrease rapidly, particularly, in the case of 75S-T. Creep and stress-rupture data are given in the table.

Magnesium

Magnesium-base alloy castings in recent years have found considerable use at temperatures up to as high as 600 or 650 F. The relatively new ZT1 alloy containing 3 thorium, 2½ zinc, and 0.7% zirconium has excellent creep properties up to 600 or 650 F and is used for engine parts.

For temperatures up to about 500 F, the magnesium alloys containing rare earth additions and zirconium have proved successful. The older magnesium aluminum-zinc alloys can be used effectively up to around 400 F, although with the introduction of newer alloys, their use is generally

limited to temperatures up to 300 F.

Tests to date indicate that resistance to corrosion and oxidation of magnesium base alloys is excellent.

Titanium

It is generally believed that titanium and its alloys will be most useful in the temperature range of from about 400 to 800 F and possibly 1000 F. Their elevated temperature properties seem to fall between those of aluminum and magnesium alloys and the heat resistant steels. A comparison with 24S and 75S aluminum indicates that commercial titanium is several times as strong as these aluminum alloys at 700 F and is equivalent to the 18:8 stainless steels.

Titanium has definite creep at room temperature while between 400 and 600 F it shows no creep. Titanium's affinity for oxygen and nitrogen is an important factor in restricting the use of sheet stock to temperatures below 1000 F. While at room and moderately high temperatures, an oxide skin forms on the metal and protects it from further oxidation, above 1000 F the metal absorbs the skin. Therefore, prolonged exposure above this temperature makes titanium brittle.

The titanium-base alloys thus far developed contain various amounts of aluminum, molybdenum, and chromium. They are age hardening and have considerably higher creep and stress-rupture strengths than commercial titanium. On a strength-weight basis they are equal to or better than Type 410 stainless in stress-rupture and creep strengths at 800 F.

High Temperature Properties of Aluminum and Titanium

Designation	24S-T Aluminum	75S-T Aluminum	Titanium (RC70)	
FORM	Wrought Sheet	Wrought Sheet	Annealed Sheet	
COMPOSITION, %	4.5Cu, 1.5Mg, 0.6Mn, Bal Al	1.6Cu, 2.5Mg, 0.2Mn, 5.6Zn, 0.3Cr, Bal Al	Commercially pure	
CREEP STRENGTH, 1000 psi at:	0.01%/1000 hr	0.01%/1000 hr	0.1%/1000 hr	
200 F	58	62	—	
300 F	52	50	—	
400 F	44	30	38	
600 F	—	—	32	
800 F	—	—	10	
RUPTURE-STRESS, 1000 psi at:	1000 hr	1000 hr	100 hr	1000 hr
200 F	55	53	—	—
300 F	37	20	—	—
400 F	19	9	45	42
800 F	—	—	22	15
THERMAL EXPANSION (in/in./°F x 10^{-6})				
68–200 F	12.8	13.0	5.0	
68–400 F	13.0	13.5	5.2	
OXIDATION RESISTANCE Max Temp for Continuous Service	Excellent oxidation resistance at all service temperatures.		1000 F	

NOTE: Values given are approximate and can vary considerably depending on exact composition, treatment, etc.

Irons and Steels

Cast Irons

Cast irons are successfully used in load carrying applications up to about 850 F. Above this temperature, all ordinary cast irons deteriorate rapidly. Based on short-time tensile tests, cast irons retain most of their tensile strengths up to about 800 F and there is little creep up to about 600 F.

Above 800 F the value of cast iron is determined by its ability to resist growth and oxidation. Of the cast irons, the higher tensile strength grades with low carbon content usually exhibit the least growth. Small additions of chromium and molybdenum aid to minimize growth in these grades. Typical applications of these irons include diesel engine cylinder heads, stoker links (up to 1400 F), cracking still tube sheets (up to 1200 F), and exhaust manifolds. Also, special alloy cast irons have been developed which have excellent resistance to growth. Of these, the austenitic cast irons are widely used. They contain 14% or more of nickel, 1 to 4% chromium, and about 5% copper. They resist scaling up to about 1500 F, and are sometimes used for automobile, truck, and bus exhaust manifolds.

Malleable Iron

Since the carbon present in malleables dissolves at temperatures above about 1400 F, malleable iron castings should not be used above 1200 F. Tensile strength properties change very little up to about 600 F; between 600 and 800 F they begin to decrease; and above 800 F they drop sharply, until at 1200 F tensile properties are approximately 20 to 25% those at room temperature. Elongation also remains practically constant up to 600 F, but above this temperature it increases rapidly. For design purposes, an allowable working strength of 5600 psi at working temperatures up to 775 F is generally used.

Malleable iron has excellent stability at elevated temperatures. Tests indicate that up to 900 F there is practically no growth or permanent increase in volume except under repeated heating. And between 900 and 1200 F there is only a slight growth.

Impact resistance, as measured by Charpy tests, is not appreciably changed up to about 400 F. In some cases, impact resistance may be lowered if castings are heated to 850 or 900 F and quenched, as in the hot

dip galvanizing process. This galvanizing embrittlement can be prevented by quenching the malleable castings from 1200 F when they are produced or by keeping phosphorus low.

Carbon Steels

Carbon steels find considerable use at temperatures above 300 F and up to 1000 F. Their oxidation resistance being satisfactory up to 1000 F, they are quite satisfactory for a wide range of applications where only low strength is needed.

As can be seen from the accompanying table, the high temperature strength properties (creep and stress-rupture) are, of course, considerably lower than those of the low alloy steels. The big advantages of low carbon steels where service conditions allow their use, are relatively low cost and ease of welding, forming and fabricating. They also have good hot impact resistance up to about 950 F.

In general, creep strength of these steels at the lower temperatures improves with an increase in carbon content, but at higher temperatures creep strength tends to decrease with increased carbon content. A normalizing heat treatment is usually recommended, since carbon steels in the annealed condition are less stable than those with normalized structures.

Molybdenum and Chromium-Molybdenum Steels

The carbon-molybdenum and chromium-molybdenum steels can be divided according to composition into four broad groups as follows: 1) carbon-molybdenum, 2) 0.5-3.0 chromium-molybdenum, 3) 4-6 chromium, 4) 6-10 chromium. All of these steels are of the pearlitic or martensitic type. They generally have low carbon content and are used in the annealed or normalized and tempered condition. Most of their use is confined to temperatures below 1200 F.

The carbon-molybdenum steels contain from 0.5 up to 1.0 or 1.5% molybdenum and up to about 0.20% carbon. Silicon up to 1.5% can be added to improve surface stability. These steels have good creep strength at intermediate temperatures, but relatively low oxidation resistance. They have low hot ductility, particularly at 950 to 1000 F, and a tendency to precipitate graphite under certain service conditions when held for long periods above 900 F. Working characteristics and weldability are excellent. They are used principally for tubing in the steam generating and oil refining industries.

High Temperature Properties of Carbon, Molybdenum, and Chromium-Molybdenum Steels

Designation	Low Carbon Steel	Carbon-Molybdenum Steels	0.5-3 Chromium-Molybdenum Steels	4-6 Chromium Steels	6-10 Chromium Steels
Form	Wrought and Cast	Wrought and Cast	Wrought and Cast	Wrought and Cast	Wrought and Cast
Composition, %	0.10-0.20 C	0.5-1.5 Mo 0.10-0.20 C	0.5-3 Cr 0.5-1.0 Mo	4-6 Cr 0.5 Mo	6-10 Cr 0.5-0.1 Mo

Creep Strength (1000 psi) at: Creep Rates: A=0.1%/1000 hr, B=0.01%/1000 hr	Low Carbon A	Low Carbon B	C-Mo A	C-Mo B	0.5-3 Cr-Mo A	0.5-3 Cr-Mo B	4-6 Cr A	4-6 Cr B	6-10 Cr A	6-10 Cr B
800 F	17-20	10-13	29-35	21-25	32-44	22-30	—	—	—	—
900 F	10-12	6-8	19-24	12-15	20-40	14-23	15-19	10-15	14-33	9-25
1000 F	3.3-5	1.8	10-12	5-7	10-20	6-12	8-11	6-7	8-12	5-9
1100 F	—	—	4	3	3-8	2-4	5-6.5	2.5-3.5	4-6	2.5-4
1200 F	0.5	0.1	2	1	2-4.5	1-2.5	2.0-3.5	1-2	2.5-3	1-2

Rupture Stress (1000 psi) at: C=100 hr, D=10,000 hr, E=100,000 hr	Low Carbon D	Low Carbon E	C-Mo C	C-Mo D	C-Mo E	0.5-3 Cr-Mo C	0.5-3 Cr-Mo D	0.5-3 Cr-Mo E	4-6 Cr C	4-6 Cr D	4-6 Cr E	6-10 Cr C	6-10 Cr D	6-10 Cr E
800 F	—	24	(For 0.5 Mo only)											
900 F	—	7	40-53	32-38	16	40-65	25-48	—	32-37	26-31	21-23	—	-40	—
1000 F	7	3	32-37	12-16	7	28-40	15-24	12-16	23-30	13-20	8-11	—	-20	—
1100 F	3	—	16-17	5-6	3	18-23	8-11	5-8	14-16	5-10	4-7	-17.5	11-14	8-11
1200 F	1.3	0.6	8	3	2	10-13	3-5.5	2-4	4-9	4-5	2-3	-10	5-7	3-5

Designation	Low Carbon Steel	Carbon-Molybdenum Steels	0.5-3 Chromium-Molybdenum Steels	4-6 Chromium Steels	6-10 Chromium Steels
Room Temp. Properties:					
Ten. Str, psi	50	55-65	55-65	60-80	70-90
Yield Str, psi	28	30-40	30-40	30-45	30-60
Elong in 2 in., %	35	30-35	30-35	35-43	30-40
Brinell Hardness	137 (Max)	150 (Max)	163 (Max)	163 (Max)	179 (Max)
Thermal Expansion (in/in/°F x 10^{-6})					
70-600 F	7.40	—	—	6.80	6.65
70-800 F	7.80	7.70-8.10	7.50-7.80	7.10	6.75
70-1200 F	8.30	8.30-8.70	8.00-8.50	7.30	7.20-7.30
Oxidation Resistance, Max Temp for Continuous Service	1050 F	1050 F	1050-1175 F	1200-1300 F	1250-1300 F
Applications	Boilers and pressure vessels, steam piping, other uses up to 1000 F where only low strength is needed.	Super heater tubing, cracking-still tubes, high temperature pipe.	Super heater and heat exchanger tubes, cracking-still tubes, steam piping, condenser tubing, steam turbine rotors.	High temperature pipe, heat exchanger and super heater tubes, hot die applications, valve and fuel injection pump parts.	Oil cracking-still tubes, exhaust valves. Used where high corrosion resistance is essential.

NOTE: Values are approximate and for steels in annealed condition. Strength properties can be improved by heat treatment.

The chromium-molybdenum steels containing up to about 3% chromium are superior to the carbon-molybdenum steels in creep and stress rupture strength. Their strength generally is satisfactory up to about 1050 F. It is considerably increased by normalizing and tempering treatments. Additions of silicon up to around 1.5% improve oxidation resistance, while adding molybdenum up to 1.0% further improves high temperature strength. All these steels have somewhat better oxidation and corrosion resistance than carbon-molybdenum steels. They are susceptible to spherodization particularly those containing over 2.0% chromium. They are moderately air hardening, but have good weldability. With proper heat treatment they can be readily formed.

The major uses of these chromium-molybdenum steels include steam piping for service up to 1000 to 1050 F; superheater, heat exchanger and condenser tubes; cracking-still tubes; and steam turbine rotors.

The 4-6 chromium steels contain from 4 to 6% chromium, and 0.5 to 0.9% molybdenum to eliminate the susceptibility to temper embrittlement and improve the high temperature strength. Silicon up to 1.5% may be added for increased creep strength or to improve oxidation resistance. These steels tend to be air hardening, which causes low ductility and poor machinability unless they are annealed and cooled very slowly. Adding titanium in amounts of four or five times the carbon content or columbium in amounts of about eight times the carbon content decreases or eliminates air hardening.

In general the high temperature strengths of 4-6 chromium steels are below those of the lower chromium grades, particularly up to about 1050 F. As a group, these steels have excellent resistance to oils and crudes containing hydrogen sulfide and therefore find wide use for tubing in oil cracking stills. Because of their high resistance to heat checking and formation of the proper amount of oxide scale, they are used in many hot die applications, such as extrusion dies, mandrels, punches and hot metal chisels. Other uses include valve and fuel injection pump parts.

The 6-10 chromium steels are similar to the 4-6 grades except for their greater chromium content, which is present to provide greater corrosion resistance primarily to hot petroleum products. In general, the corrosion resistance is increased up to four times that of the 4-6 chromium grades.

The increased chromium content does not improve the high temperature strength characteristics, but actually tends to decrease creep strength. However, molybdenum in amounts up to 1.0% increases creep strength so that it is equal to or higher than the lower chromium grades. Stress rupture values vary considerably, but in general improve with chromium content up to about 7.0%. From 7 to 9% chromium, stress rupture strengths decrease, but additions of molybdenum up to around 1% counter balance this decrease. Although they are readily welded, the 6-10 chromium grades air harden during welding. The 6-10 chromium steels find use in exhaust valves and in the petroleum refining field for oil cracking still tubes where high corrosion resistance is required.

High Temperature Properties of Straight Chromium Steels

Designation	Martensitic Grades: 403, 410, 416, 420		Ferritic Grades: 405, 430, 446	
FORM	Wrought		Wrought	
CREEP STRENGTH (1000 psi) at:	A	B	A	B
800 F A=0.1%/1000 hr	—	—	—	—
900 F B=0.01%/1000 hr	—	—	—	—
1000 F	9.2	8	6-8.5	4.2-7
1100 F	4.2	3.5	3-5	2.3-4.5
1200 F	2	1.3	1.5-2.2	1.0-1.6
RUPTURE STRESS (1000 psi) at:	C		C	
900 F C=10,000 hr	26		24	
1000 F	13		13	
1100 F	7		5	
1200 F	3		3	
ROOM TEMP. PROPERTIES				
Ten. Str, psi	75-115		75-85	
Yield Str, psi	40-90		40-55	
Elong in 2 in., %	20-30		25-30	
Brinell Hardness	150-180		160-180	
THERMAL EXPANSION (in/in/°F x 10^{-6})				
70-800	6.41		—	
70-1200	6.70		—	
OXIDATION RESISTANCE MaxTemp for Continuous Service	1300-1400		1500-2000	
APPLICATIONS	Steam turbine blading, valve trim, pressure vessel liners, oil industry tubing, gas turbine compressor blading.		Pressure vessel liners. Used where high resistance to scaling is needed.	

NOTE: Values are approximate and can vary considerably depending on exact composition, heat treatment, etc.

Straight Chromium Steels

The straight chromium stainless steels, which are those containing from about 11 to 27% chromium, can be divided into two main groups: 1) the martensitic grades which include AISI Types 403, 410, 416, 420, and 431; 2) the ferritic grades which include AISI Types 405 and 446. Type 430 may be either martensitic or ferritic depending on the exact chromium content. While these steels resist oxidation up to as high as 2150 F, they do not maintain high strength much above 1250 F.

Of the martensitic grades, the most widely used are those containing 11.5 to 14.0% chromium. They have good forming properties, good corrosion resistance, ability to be heat treated to high hardness, and are reasonable in cost compared to the more highly alloyed metals. They are not subject to temper embrittlement. In the annealed condition

High Temperature Properties of Austenitic Stainless Steels

Designation	*Types 304, 316, 321, 347 (18:8)		Types 309 (25:12)		Types 310, 314 (25:20)	
FORM	Wrought		Wrought		Wrought	
CREEP STRENGTH (1000 psi) at: Creep Rates: A=0.1%/1000 hr; B=0.01%/1000 hr	A	B	A	B	A	B
1000 F	17–25	12–17	15.9	—	17	17
1100 F	12–18.2	7.5–11.5	11.6	—	13–14	13
1200 F	7–12.7	4.5–7	8	4	9	8
1300 F	4–7.9	2.5–4	4.5	2	5–6.5	5
1500 F	1.2–2.8	1.0–2	1.0	.5	1–2.5	2
RUPTURE STRESS (1000 psi) at: C=10,000 hr; D=100,000 hr	C	D	C	D	C	D
900 F						
1000 F	27–40	20–35	—	—	27	
1100 F	17.5–28	13.5–25	—	—	18	15
1200 F	11–17	7.5–14	14	10	12	9
1300 F	6–10	4–7	7.5	4.5	7.5	5
1500 F	2.5–3	2–3	2.5	2	2.5	2
ROOM TEMP. PROPERTIES						
Ten. Str, psi	85		95		100	
Yield Str, psi	35		40		45	
Elong in 2 in., %	60		45		45	
Brinell Hardness	155		170		180	
THERMAL EXPANSION (in/in/°F x 10^{-6})						
70–800	10.2		9.5		9.3	
70–1200	10.7		9.7		9.9	
OXIDATION RESISTANCE, Max Temp for Continuous Service	1650 F		2000 F		2050 F	
APPLICATIONS	Steam pipe and boiler tubes, radiant superheaters, oil-refinery still tubes, turbine parts, jet engine exhaust cones.		Superheater and furnace parts, jet engine exhaust cones.		Gas-turbine combustion chamber parts, hydrogenation plants, flame tubes.	

NOTE: Values are approximate and can vary considerably depending on exact composition, heat treatment, etc.
** Upper range of values of creep and stress-rupture strength are those of Type 316.*

their elevated temperature strength is somewhat less than the 9% chromium steels. They are distinctly air hardening which can be an advantage where high hardness is desirable, but may be a disadvantage where the annealed material must be welded.

Principal uses of the 11.5 to 14% grades are liners for pressure vessels, valves and valve trim, turbine blading, oil industry tubing. Not too much high temperature use is made of the higher chromium content grades.

The ferritic straight chromium grades find only limited high temperature use. Most of them are susceptible to temper embrittlement and have relatively low high temperature strength. However, Type 405, containing 12% chromium and 0.10-0.30% aluminum is finding use for gas turbine compressor blades operating in the lower temperature range. It is also used in heat exchanger tubing and for liners in pressure vessels. Because of its low air-hardening characteristics, it serves in place of Type 410 in application where welding is required, but where high hardness is not needed. Ferritic Types 430 and 446 are largely limited to uses where excellent oxidation resistance is required.

Austenitic Stainless Steels

As a group, the chomium-nickel austenitic stainless steels show excellent performance at elevated temperatures. They are used most widely for applications in which good load carrying ability is required above 1200 F. Of all the commonly used metals, only the specialized superalloys (covered in a later section) surpass them in high temperature strength.

For our purposes here (and in the table) the austenitic chromium-nickel stainlesses have been broadly divided into three groups: 1) the 18:8 grades including the basic Types 302, 304 and the modified grades—Type 316 with molybdenum, Type 321 with titanium and Type 347 with columbium; 2) the 25:12 grade, Type 309; and 3) the 25:20 grades, Types 310 and 314.

In general, all the austenitic stainless steels have excellent resistance to scaling at high temperatures and it improves with increasing chromium content. The 25:20 and 25:12 grades resist scaling up to about 2000 F; the 18:8 grades are satisfactory up to about 1600 F. In high temperature load carrying ability, most of the grades are comparable up to about 1500 F, except molybdenum modified Type 316, which is significantly higher than the other grades in creep and stress-rupture strength. Above about 1500 F, the higher chromium grades, 25:12 and 25:20, are more generally satisfactory since excessive scaling in the 18:8 grades can lead to failures.

All austenitic stainless steels, except the modified grades, Types 321, 347 and 316, are subject to carbide precipitation when heated in the range from about 900 to 1300 F. If the steels are then used under certain corrosive conditions, at room or slightly elevated temperatures, this carbide precipitation can lead to intergranular corrosion or oxidation. However, no general rules can be drawn, and each application must be judged independently.

Austenitic stainlesses have high coefficients of thermal expansion and

low thermal conductivity compared to other steels used in high temperature service. Thus, their thermal ductility or themal shock characteristics are relatively low. They also have a tendency to carburize more rapidly than other steels.

All chromium-nickel steels are readily welded by the common welding methods. Where intergranular corrosion is a problem, and welding must be used, the carbon content should be below 0.08 to 0.10% or one of the stabilized grades should be used. Stainless steels can be readily worked and formed by the usual commercial methods if proper procedures are used.

Heat Resistant Casting Alloys

All the common heat resistant casting alloys can be grouped according to composition and metallurgical structure into three broad groups as follows: 1) iron-chromium, 2) iron-chromium-nickel, and 3) nickel-chromium-iron.

The iron-chromium or straight chromium alloys have up to 30 chromium and up to 7% maximum nickel. They are predominantly ferritic and, therefore, have relatively low hot strength. They are seldom used in critical load bearing parts at temperatures above 1200 or 1400 F. They have found considerable use in applications involving uniform heating and severe atmosphere conditions, such as in high sulfur firing.

The iron-chromium-nickel alloys are partially or completely austenitic. They contain between 18 and 32% chromium, and 8 to 22% nickel, with the chromium content always being greater than the nickel. They are characterized by good high temperature strength, hot and cold ductility, resistance to oxidizing or reducing conditions. They also have good weldability and generally machine satisfactorily. It is important to use these high chromium contents when the atmospheres are high in sulfur, particularly if reducing conditions are encountered.

The nickel-chromium-iron casting alloys are nickel predominating and are austenitic. They contain from about 10 to 20 chromium and from about 30 to 70% nickel. The composition limits are not as critical as for the iron-chromium-nickel types, and there is no evidence of formation of a brittle phase at service temperatures. If it were not for their relatively high cost and the problem of corrosion in high sulfur atmospheres, these alloys could be used satisfactorily for practically all applications up to 2100 F. They have good hot strength, carburization resistance, and thermal fatigue resistance. Therefore, they find wide use for load bearing applications and for castings subject to large temperature differentials and cyclic heating. Although they will withstand reducing and oxidizing atmospheres satisfactorily, they have low resistance to corrosion in high sulfur atmospheres.

The table gives the range of creep strengths for the three groups of heat resistant casting alloys. From the table it is evident that the nickel-chromium grades have highest creep strengths up to around 1600 F and therefore, are generally preferred for high load applications where atmospheric conditions permit. Above about 1650 F, the iron-chromium-nickel alloys with nickel on the high side are superior. In general, stress rupture data rank the alloys in much the same order as the creep strength.

In hot ductility, the nickel-chromium grades rank highest up to 1800, followed by the iron-chromium-nickel alloys. Above this temperature all have adequate ductility. The iron-chromium-nickel alloys containing 8-14% nickel may (depending on the exact composition) de-

High Temperature Properties of Heat Resistant Casting Alloys

ACI Designation	Iron-Chromium Alloys HC, HD		Iron-Chromium-Nickel Alloys HE, HF, HH, HI, HK, HL		Nickel-Chromium Alloys HT, HU, HW, HX	
COMPOSITION, %	26–30% Cr, 7% Ni max		18–32% Cr, 8–22% Ni		10–20% Cr, 30–70% Ni	
CREEP STRENGTH (1000 psi) at: Creep Rate: 0.1%/1000 hr						
1400 F	1.2–3.5		3.5–7		6–8.5	
1600 F	0.7–1.9		2–4.3		3–5	
1800 F	0.4–0.9		1–2.7		1.4–2.2	
2000 F	—		0.3–1		0.5–0.6	
RUPTURE STRESS (1000 psi) at:	100 hr	1000 hr	100 hr	1000 hr	100 hr	1000 hr
1200 F	—	—	30–35	17–22	—	—
1400 F	3–10	2–	10–15	8–10	10–18	7.5–12.5
1600 F	1.5–5	1.2–	5–9.2	3.5–5	6–8.5	4–7
1800 F	0.8–2.5	0.6–	2.2–5.2	1.5–3	3.5–4.5	2.2–3.7
2000 F	—	—	–2.5	–1.2	1.7–2.5	0.9–1.8
ROOM TEMP. PROPERTIES (as cast):						
Ten. Str, 1000 psi	70–85		75–85		60–70	
Yield Str, 1000 psi	48–65		45–55		25–40	
Elong in 2 in., %	2–16		10–35		4–9	
Brinell Hardness	180–200		165–200		168–179	
THERMAL EXPANSION (in/in./°F x 10^{-6})						
70-1200 F	6.3–7.7		9.5–10		8–9	
70-1600 F	6.8–8.5		9.7–10.5		8.6–9.3	
70-2000 F	7.7–9.2		10.9–10.9		9.2–9.8	
OXIDATION RESISTANCE, Max Temp for Continuous Service: (low sulfur)	1700–1900 F		1600–2100 F		1900–2100 F	

NOTE: *Values given are approximate and can vary considerably above or below these values depending on exact composition, aging, treatment, method of manufacture, and method of test.*

velop the brittle sigma phase if used between 1200 and 1650 F.

Little precise thermal fatigue information is available. However, field experience indicates that thermal fatigue resistance increases with increasing nickel content. Thus, the nickel-chromium alloys are rated highest followed by the iron-chromium-nickel grades.

In general, where only air corrosion is involved most of the standard grades will give satisfactory service up to at least 1900 F. Where reducing atmospheres are involved, with no sulfur, most of the grades are satisfactory up to at least 1700 F. In applications where high sulfur gases (over 100 grains S per 100 cu ft) under reducing conditions are encountered, only the high chromium grades are suitable. The high nickel grades are particularly susceptible to corrosion in high sulfur atmospheres, and their use must be avoided in such applications.

All heat resistant casting alloys pick up some carbon in carbon bearing atmospheres at high temperatures. However, resistance to carbon penetration increases as nickel content increases. The chromium predominating grades are generally not considered suitable for carburizing service, but if used, silicon content should be kept on the high side and be closely controlled.

In many applications where heat resistant alloys are used, abrasion resistance is important. In general iron-chromium grades, with their high abrasion resistance, are selected for such service.

All heat resistant alloys can be welded by conventional methods where weld metal of equivalent properties is used. The high nickel grades, as a group, are easiest to weld. The austenitic grades are relatively easily welded, but difficulties are sometimes encountered with the ferritic grades.

The use of heat resistant castings is wide and varied. In the heat treating furnace and equipment field they are used as pots for molten salt and metal baths; as structural parts, such as roller hearths, walking beams and chain conveyors; as containers for carburizing and annealing; and for a multitude of other uses, such as baskets, fixtures, annealing hoods, radiant heater tubes, and thermocouple protection. In the steel industry blast furnace blowpipes, hot-blast valves and rolling mill guides are only a few typical applications. In oil refineries and process industries large amounts of heat resistant castings are used as tube supports, valve bodies and fittings, burner nozzles, and beams and channels.

Heat resistant castings also find extensive use in the glass, ceramic, cement mill and ore reduction industries for such applications as cooler spouts, outlet grates, kiln feed parts, chain conveyors, rabble holders and blades. Exhaust manifolds, collector rings, valves and choke tubes of heat resistant alloys are commonplace in heavy duty internal combustion engines, while their application to jet engines and gas turbines is just beginning to be explored.

Bolting Steels

Steels used for high temperature bolts, as covered in ASTM Specification A193-52T, include chromium-molybdenum low-alloy steels (AISI 4140, 4142, 4145); chromium-molybdenum-vanadium low-alloy steels containing 0.20 to 0.35 vanadium, 0.80 to 1.15 chromium and 0.30 to 0.65% molybdenum; 5% chromium (Type 501 modified) and 12% chromium (Type 416) steels; and austenitic chromium-nickel steels (Types 304, 347, 321 and 303). Some of the pertinent high temperature properties of these materials are given elsewhere under the discussions of the materials groups to which they belong.

The low-alloy steels listed above have widest use for high temperature bolting and are usually used in either the liquid-quenched and tempered or in the normalized and tempered condition. Although some of these compositions are used at temperatures up to 1200 F, they are most commonly applied where temperatures range from 750 to 1050 F.

The straight chromium and austenitic grades are used under corrosive conditions or at temperatures where the low-alloy steels are not satisfactory.

Exhaust Valve Materials

Steels and alloys for valves and valve seats in internal combustion engines must have a combination of high hot hardness, resistance to stretching at operating temperatures and good resistance to the products of combustion. In automotive valves, the operating temperature is from around 1300 to 1600 F, and in some cases may reach 1900 F. In aircraft engines, the valves are internally cooled with sodium, so the maximum temperature is about 1200 F.

Many different compositions are being used for valve applications. Perhaps the most widely used are the martensitic or pearlitic steels containing up to 20% chromium and up to 4% silicon. Some of these steels also have additions of tungsten, nickel and molybdenum.

For years the standard steels for automotive valves have contained 5 to 10% chromium and 1 to 4% silicon. Where service temperatures are low, automotive intake valves have been commonly made of low alloy steels (such as 4047, 4140 and 8640) with about 0.35 to 0.5% carbon. Austenitic steels and alloys with silicon contents up to around 3% are also used as valve materials. A relatively recent trend has been to more highly alloyed steels because of the corrosive action of tetra-ethyl lead or other anti-knock additions to fuels.

In some valve applications, the seat is faced with Stellite, a chromium-cobalt-tungsten alloy, or Brightray, a 20 chromium-80% nickel alloy. Stellite has good high temperature hardness, but is somewhat low in resistance to corrosion, by leaded fuels. Brightray has better corrosion resistance than Stellite, but is lower in hardness.

Superalloys

The so-called superalloys are used for elevated temperature service above 1200 F. There are a number of different ways of classifying them. Here they will be divided into four major groups as follows: 1) wrought austenitic non-heat treatable steels, 2) wrought heat treatable, or precipitation hardening austenitic steels, and cobalt base alloys, 3) cast cobalt base alloys, and 4) nickel base alloys.

Representative superalloys and their

compositions are given in an accompanying table.

Austenitic Alloys

The first group are the materials commonly used in the as-worked or in the hot-cold worked condition and find most use in the range of from 1000 to 1400 F. They are primarily low-carbon, chromium-nickel-iron alloys, with one or more carbide forming elements such as molybdenum, tungsten, titanium, and columbium.

They have higher creep strength than the regular austenitic stainless steels and yet retain their good forming properties. Optimum creep and stress rupture strengths are obtained by hot-cold working from 1200 to 1400 F. They have excellent surface stability provided proper precautions are taken to prevent carbide precipitation. Their main uses are as forgings for turbine disks and wheels, and for blading where high strength from about 1000 to 1300 F is required. Other uses include ducts, collector rings, bolts and exhaust cones.

The second group of superalloys are also mostly chromium-nickel-iron steels, but are generally heat treated to produce the optimum high temperature properties. Wrought cobalt-chromium-nickel alloys also are included in this group.

The optimum high temperature strength properties are obtained in these alloys by precipitation or age hardening treatments. Generally the higher the solution temperature, the greater the elevated temperature strength, but the lower the ductility.

The high temperature strengths of alloys in this group are generally somewhat higher than Group 1. The alloys such as Discaloy, A-286 and Refractaloy 26 have good strength up to about 1350 F and satisfactory oxidation resistance to 1500 F. Others in this group, particularly the cobalt base alloys such as Refractaloy 70, have good strength properties up to 1500 F. Principal uses of these materials include gas turbine blades, bolts, diaphragms, disks, shrouding, and tail cones.

Cast Cobalt Base Alloys

The third group are the cast cobalt base alloys and are customarily produced as precision castings. They contain from about 30 to 65% cobalt with about 17 to 30% chromium, and smaller amounts of nickel, molybdenum, tungsten and columbium. These alloys are age hardened for optimum properties. One successful treatment is an aging temperature of 1350 F for about 50 hr.

The cobalt base castings are suitable for use at higher temperatures than any of the other superalloys. At 1500 F they have stress rupture values at 100 hr of up to 29,000 psi, and at 1000 hr of up to 25,000 psi. At 1600 F the values for 100 and 1000 hr are 21,000 and 17,000 psi respectively.

Cast cobalt alloys also have excellent oxidation corrosion resistance at high temperatures which makes them suitable for many and diverse applications. These include valves, gas turbine blades, heat exchangers, nozzle vanes, tail cones and turbo-supercharger blades.

Because of their high cost and the scarcity of cobalt, their use does not become economical until temperatures exceed about 1300 F and where strengths higher than those possible with other alloys are required.

Nickel Base Alloys

The fourth group, the nickel base alloys, contain from about 60 to 80% nickel and are available in wrought and cast form. They offer excellent oxidation and corrosion resistance up to 2100 F.

One series of alloys within this group known as the Inconels (Nimonic in England) contain about 75% nickel. Inconel is particularly useful for service involving high temperatures where cyclic heating and cooling and large temperature gradients exist. Inconel X and Inconel W are precipitation hardening and develop much higher elevated strength properties. They are used for high stress applications up to 1500 F and

High Temperature Properties of Superalloys

	Group 1 Non Heat-Treated Chromium-Nickel-Iron Steels	Group 2 Heat-Treated Chromium-Nickel-Iron Steels Wrought Cobalt-Base Alloys	Group 3 Cast Cobalt-Base Alloys	Group 4 Nickel-Base Alloys
FORM	Wrought	Wrought	Cast	Cast and Wrought
USUAL CONDITION	As-worked or hot-cold worked	Solution treated + age hardened	As-cast or solution treated + age hardened	As-cast or annealed
RUPTURE STRESS (1000 psi) for 1000 hr at:				
1200 F	35–42	35–51	44–47	30–65
1300 F	20–26	23–38	30–40	25–45
1400 F	12–16	18–25	15–26	12–28
1500 F	9–12	11–20	14–25	10–20
1600 F	—	9–15	12–17	—
THERMAL EXPANSION (in/in/°F x 10^{-6})				
70-1000 F	9.30–9.80	8.2–9.8	7.90–8.40	6.65–8.0
70-1500 F	9.70–10.0	8.8–9.7	8.40–9.25	6.95–9.0
OXIDATION RESISTANCE—Max Temp. for Continuous Service	1600 F	1600–1900 F	1900–2100 F	2100 F
APPLICATIONS	Principally forgings for gas turbine disks and wheels.	Gas turbine blades, bolts, diaphragms, disks, shrouding, tail cones.	High temperature valves, gas turbine blades, nozzles, tail cones.	Furnace parts, collector rings, exhaust stacks, combustion chambers in aircraft.

NOTE: Values are approximate and can vary considerably depending on exact composition, heat treatment, etc.

under certain conditions up to 1600 F. Above 1500 F their oxidation resistance is somewhat lower than Inconel. They can be hot- and cold-worked satisfactorily.

Another series of nickel base alloys, known as the Hastelloys, is used in the high temperature field particularly for furnace parts and in

Representative Superalloys

Alloy	Approximate Composition, %											
	Cr	Ni	Mo	Co	Fe	Cb	Ti	W	Mn	Si	C	Other
Group 1—Chromium-Nickel-Iron Steels (Not Heat Treated)												
19 DI	18/22	8/10	1/1.5	—	Bal	0.2/0.6	0.2/0.6	1/1.5	1.0	0.5	0.26/0.36	
19-9 WMo	18/22	8/10	0.2/0.5	—	Bal	0.2/0.6	0.2/0.6	1/1.5	0.60	0.42	0.11	
16-25-6 (Timken)	15/17	24/27	5.5/7.0	—	Bal	—	—	—	1.0	0.5	0.12 max	0.1/0.2N
17 W	13	20	1.0	—	Bal	—	—	2.2	0.6	1.0	0.45	
CSA(4275 Mod. and 234-A-5)	18.5	5.5	1.35	—	Bal	0.5	—	1.2	4.5	0.5	0.25	
Gamma Columbium	15	25	4	—	Bal	2	—	—	1.0	1.0	0.4	
Group 2—Chromium-Nickel-Iron Steels and Wrought Cobalt Base Alloys (Heat Treatable)												
N 153	17	15	3	13	Bal	1	—	2	1.5	0.5	0.10	0.15 N
Discaloy	13.5	26	3	—	54	—	1.5	—	0.8	0.5	0.03	0.2 Al
A-286	15	26	1.3	—	Bal	—	1.9				0.08	0.35 Al, 0.3 Va
R. ex 78	14	18	3.8	—	Bal	—	0.6	—	0.8	0.7	0.07	3.6 Cu
R. ex 337A	14.5	18	3.75	7	Bal	—	0.8	—	0.7	0.9	0.25	3.5 Cu
S 495	14	20	4	—	Bal	4	—	4.0	1.0	0.5	0.45	
18-14 S-Mo	18	13.5	2.9	—	Bal	—		—	1.90	0.66	0.06	
ATV-3	15	20	4	—	53	4	—	4	0.7	0.9	0.5	
S B 16	19	20	4	41	3	4	—	4	1.5	0.6	0.4	
Refractaloy 26	18	38	3	20	16		3		0.8	1	0.03	0.2 Al
N 155 (Multimet)	20/22	19/21	2.5/3.5	18/21	Bal	0.75/1.25		2/3			0.08/0.16	0.10/0.20 N
S 590	20	20	4	20	27	4	—	4	1.5	0.6	0.5	
S816	20	20	4	45	3	4	—	4	1.5	0.6	0.4	
Refractaloy 70	20	20	8	30	15	—	—	4	2	0.2	0.05	
Group 3—Cast Cobalt Base Alloys												
HS21	25/30	1.5/3.5	4.5/6.5	Bal	2 max	—	—	—	0.3	0.6	0.20/0.35	
HS23 (61)	23/29	1.5 max		Bal	2 max	—	—	4/7	0.3	0.6	0.35/0.50	
HS25 (L-605)	19/21	9/11	—	Bal	2 max	—	—	14/16	1/2	1 max	0.15 max	
HS27 (6059)	23/29	Bal	5/7	30 min	2 max	—	—	—	0.5	0.4	0.35/0.50	
HS30 (422-19)	23/29	13/17	5/7	Bal	2 max	—	—	—	0.5	0.4	0.35/0.50	
HS31 (X-40)	23/28	9/12	—	Bal	2 max			6/9	0.6	0.7	0.45/0.60	
HS36 (Lo-251)	18/20	9/11	—	Bal	2 max	—	—	14/15	1.5	0.5	0.35/0.45	0.03 B
S816	20	20	4	45	3		—	—	0.7	0.5	0.45	4 Cb
NR 90	25	19	4.6	44	0.5		—	5.3	0.7	1.0	0.50	
X-50	25	10	—	55	0.6		—	7	0.6	0.7	0.5	
Group 4—Nickel Base Alloys												
Hastelloy B	—	Bal	26/30	—	4/7	—	—	—	0.6	0.2	0.12 max	0.3 V
Hastelloy C	16/18	Bal	16/18	—	4.5/7	—	—	3.8/5.3	—	—	0.15 max	
Inconel	15	76	—	—	8	—	—	—	0.25	0.25	0.1	
Inconel X	14/16	70 min	—	—	5/9	0.7/1.2	2.3/2.8		0.7	0.4	0.08 max	0.7 Al
Inconel W	14	75	—	—	6	—	2.5		—	—	0.05	0.6 Al
Waspalloy	19	Bal	3	14	1	—	2.4		0.9	0.6	0.08	1–3 Al
Nimonic 80	21	Bal	—	—	<1	—	1.8/2.7	—	0.5	0.5	0.04	0.5/1.8 Al
Nimonic 75	18/21	Bal	—	—	5 max	—	0.2/0.6	—	1.0 max	1.0 max	0.08/0.15	

components for gas turbines. These nickel-molybdenum alloys are used in both wrought and cast form. Their elevated temperature properties lie between those of the iron-base and the cobalt-base alloys.

Besides the above, there are a group of nickel base alloys containing from about 30 to 70% nickel which are utilized almost entirely in cast form. These are discussed in the section on heat resistant castings.

Chromium, Molybdenum

There are a number of metals with a higher melting point than the superalloys. Here space permits only brief mention of a few which seem to show most promise for future use.

Chromium-base alloys have received considerable attention in recent years. Cast chromium-base alloys with about 60 chromium, 23 iron, 15 molybdenum, and 2% titanium have been produced which at 1600 F are about two times as strong as cobalt-base alloys. Another alloy containing 30 iron, 4 titanium, 9% molybdenum and the balance chromium has been developed and has better stress rupture strength than S-816 superalloy. Another similar alloy with aluminum replacing a portion of the titanium has a rupture time of 300 hr at a stress of 28,000 psi. The principal disadvantage of these chromium-base alloys is their lack of room-temperature ductility.

Another promising high temperature metal is molybdenum. The pure metal has shown better high temperature strengths than the best superalloys in the range from 1600 to 2000 F. Work has also been done on alloys of molybdenum containing small additions of either titanium, columbium, vanadium or cobalt. At 1600 to 1800 F, stress-rupture strengths of these alloys are in the upper range of pure molybdenum; at 2000 F the alloys show greater strengths than does pure molybdenum.

Unfortunately the surface stability of molybdenum and the alloys thus far developed is not good at elevated temperatures. The metal oxidizes rapidly, and evaporates at appreciable rates above 1400 F. To obtain economical life, some means of protecting the surface must be developed. Cladding, electroplating, siliconizing and ceramic coating give promise toward accomplishing this.

The room temperature ductility of molybdenum is relatively good, and it is quite ductile at high temperatures.

Ceramics

Ceramics' most outstanding characteristic is high refractoriness, and for years they have been used as a refractory material in industry. But only since World War II has active development taken place on high strength ceramics. Before this the best materials in use industrially were the mullite and high aluminum oxide bodies which were used for spark plugs, pyrometer tubes, furnace bricks, etc.

The most important high temperature ceramics at present are compositions that contain combinations of refractory oxides of the following elements: beryllium, aluminum, zirconium, thorium, magnesium and calcium. Typical ceramics developed by the Bureau of Standards contain large percentages of beryllium oxide or zirconium oxide with smaller quantities of the oxides of magnesium, calcium, silicon, titanium or boron. The accompanying table shows the melting point and coefficient of thermal expansion of most of these oxides. Another table gives stress-rupture and creep strength

Approximate Properties of Ten Oxides

Oxide	Melting Point, F.	Thermal Expansion in/in./°F. 10^{-6}*
ThO_2	5500	5 x 10
MgO	5100	8
ZrO_2	4900	3-6
CaO	4700	8
CeO_2	4700	—
BeO	4500	5
Cr_2O_3	4450	7
Al_2O_3	3750	5
SiO_2	3100	7
TiO_2	3100	4

** In most cases, room temperature to 1800 F.*
From paper by H. C. Cross presented at Basic Materials Conference, 1953

High Temperature Strength of Some Ceramics

Compositions	Stress-Rupture Strength, psi 100 hr at 1900 F	Creep Strength, psi at 1800 F 0.1% per 1000 hr
$48BeO:2Al_2O_3:ZrO_2$+2% (by wt) CaO	16,000	10,000
$MgO:5BeO:ZrO_2$	12,000	—
$3MgO:5BeO:3ZrO_2$	10,000	5000
$3MgO:5BeO:8ZrO_2$	8000	5000
$MgO:6BeO:3ZrO_2$	10,000	5000
$160BeO:2Al_2O_3:ThO_2$+2% (by wt) TiO_2	—	4000

From NACA Tech. Note 1561, by Burdick, Moreland, and Geller

data on some typical high temperature ceramic compositions.

In general, it can be stated that ceramic materials have higher strengths than superalloys at 2000 F and above. Their superiority is even greater when comparison is made on a strength-weight basis. Also at temperatures above 2000 F, their oxidation resistance is superior to the superalloys and most cermets (discussed below). However, ceramics are brittle and they have relatively low resistance to thermal shock, and this limits their use.

Besides the oxides, graphite, carbides, nitrides, and borides can be classed as ceramics. Of these, graphite probably has widest commercial use. It has an extremely high softening point and resists chemical attack at high temperatures well. Its strength does not decrease at the temperatures met in commercial heating applications. It resists thermal shock and has an unusually low temperature coefficient of expansion. In addition, its thermal conductivity decreases as temperature increases. One drawback is its tendency to oxidize. It must be kept out of contact with air and oxygen at temperatures above 842 F. Graphite is commonly used for welding tips, furnace electrodes, electrical contacts and refractory products.

Cermets

The so-called cermets can be described broadly as refractory metallic compounds combined with metals and fabricated primarily by powder metallurgy methods. The compounds which have received most attention are oxides, borides, carbides, nitrides and silicides, and the future may see most of these in commercial use. To date, however, the titanium carbides and aluminum oxides seem to possess the best all-around characteristics and seem to show most promise for commercial use.

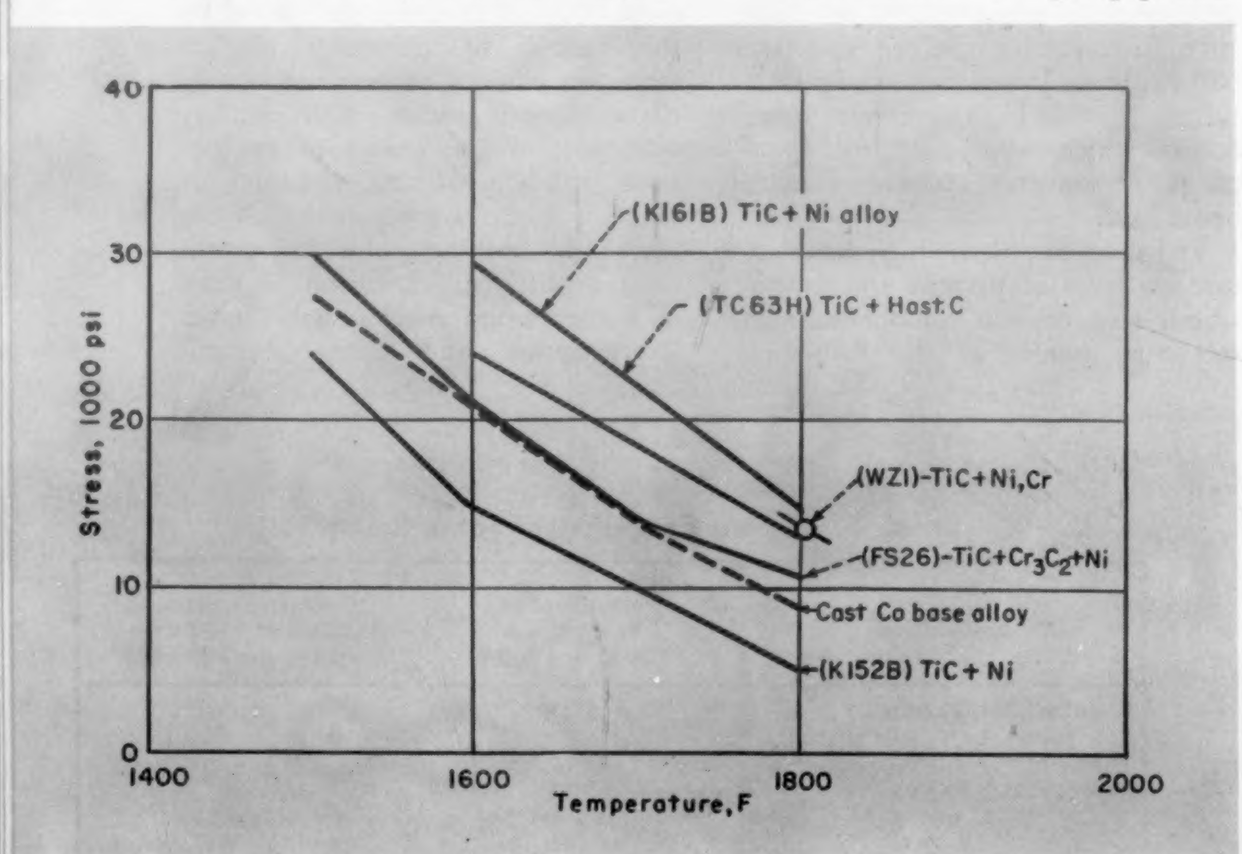
The titanium-carbide-base cermets presently developed contain from around 50 to 90% titanium carbide. Nickel, cobalt and chromium, used alone or together, are added as binders in amounts from about 10 to 50%. A relatively recent trend is the use of high temperature alloys (such as nickel or cobalt base alloys, and stainless steels) for binders.

Both thermal and strength properties are affected by the type and amount of metal binder; room temperature strength increases with the amount of metal binder, but high temperature strength is lowered. Also the alloy binders apparently give higher strength values than the pure metal binders.

These materials as a group possess high strength and resistance to oxidation at elevated temperatures. They have high thermal conductivity which contributes to their good thermal shock resistance. Their big disadvantage now is poor resistance to impact.

In general, high temperature strengths of these cermets run higher than those of other superalloys. Stress rupture values for 1000 hr average around 21,000 psi at 1600 F, and about 9000 psi at 1800 F. The properties of titanium carbide cermets show great promise for use in gas turbine engines.

Typical of the aluminum oxide base cermets under development is the one now being used successfully for thermocouple protection tubes. It contains 77% chromium and 23% aluminum oxide. This material resists oxidation up to 2200 F and combustion gases up to 3100 F. Other potential uses include burner tips, flame nozzles and crucibles.



Stress for rupture in 100 hr of some titanium carbide cermets.

(From an AIME paper, Feb. 1954, "Contribution of Powder Metallurgy to the High Temperature Material Problem", by G. M. Ault and G. C. Deutsch)

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Approximately Equivalent American and Foreign Specifications for Aluminum Casting Alloys

(Based on Composition)

ASTM[1] B179-51T	SAE[2]	BS1490[3] (British)	CSA[4] (Canada)	DIN 1725[5] (Germany)	BNF[4,6] (France)	CIMNF[2] (France)	VSM[4] (Switzerland)	UNI[2] (Italy)
CG100A	34	LM-12	HA10.250	—	A-U10G	—	—	3041
CN42A	39	LM-14	HA 9.218	—	A-U4N	2A-U4NL	—	3045
C4A	38	LM-11	HA 9.226	—	A-USGT	—	G Al-Cu-Ti	—
CS72A	33	LM-1	—	G AlCuSi	—	2A-SUH	—	—
G4A	320	LM-5	—	G AlMg5	A-G3T, A-G6	—	G Al-3Mg	3058
G10A	324	LM-10	—	—	—	—	—	3056
S5A	35	LM-18	HA 9.123	—	—	—	—	—
S12A (S5, S9)	305	LM-6, LM-20	HA 9.160	G AlSi(Cu), G AlSi, GD AlSi13	A-S13	2A-S13L	G Al-12Si, G Al-Si-Cu	3047, 3048
SC51A	322	LM-16	HA 9.125	G AlSi5Cu1	—	—	—	3053
SC54A-B (SC2, SC5)	307, 330, 326	LM-4	HA 9.117	G AlSi6Cu3	—	2A-S5UL	—	3052
SG70A	323	LM-8	HA10.135	G AlSi5Mg	A-54G	—	G Al-5Si-Mg	3054
SG100A (SG2, SG3)	309	LM-9	—	G AlSiMg	A-S10G	2A-S10GL	G Al-10Si-Mn-Mg	3049
SN122A	321	LM-13	HA10.162	—	A-S12UN	2A-S12UN	—	3050

[1] *Ingots.* [2] *Sand, pressure and pressure die castings.* [3] *Ingots and castings.* [4] *Sand and gravity die castings.* [5] *Sand and gravity die castings (G) and pressure die castings (GD).* [6] *Draft.*
NOTE: This is not the complete list of ASTM alloys specified in B179-51T; it consists only of those alloys for which foreign equivalents are available.

Composition Limits (%) ASTM Specification B179-51T

Alloy	Copper	Iron	Silicon	Manganese	Magnesium	Zinc	Chromium	Titanium	Nickel	Tin	Other (total)
CG100A	9.2/10.8	1.2	2.0	0.5	0.20/0.35	0.4	—	0.2	0.3	—	0.3
CN42A	3.5/4.5	0.8	0.7	0.3	1.3/1.8	0.3	0.2	0.2	1.7/2.3	—	0.15
C4A	4.0/4.5	0.8	0.5/1.5	0.3	0.03	0.3	—	0.2	—	—	0.15
CS72A	6.0/8.0	1.2	1.0/4.0	0.5	0.07	2.5	—	0.2	0.3	—	0.5
G4A	0.1	0.4	0.3	0.3	3.5/4.5	0.1	—	0.2	—	—	0.15
G10A	0.2	0.2	0.2	0.1	9.5/10.6	0.1	—	0.2	—	—	0.15
S5A	0.1	0.6	4.5/6.0	0.3	0.05	0.3	—	0.2	—	—	0.05[1]
S12A (S5, S9)	0.6	0.8	11.0/13.0	0.3	0.1	0.3	—	—	0.5	0.1	0.2
SC51A	1.0/1.5	0.6[2]	4.5/5.5	0.5[2]	0.4/0.6	0.3	0.2	0.2	—	—	0.15
SC54A-B (SC2, SC5)	3.0/4.0	1.0	4.5/5.5	0.5	0.1	0.9	—	—	0.5	0.3	0.5
SG70A	0.2	0.5	6.5/7.5	0.3	0.2/0.4	0.3	—	0.2	—	—	0.15
SG100A (SG2, SG3)	0.6	0.8	9.0/10.0	0.3	0.4/0.6	0.3	—	—	0.5	0.1	0.2
SN122A	0.5/1.5	1.0	11.0/13.0	0.1	0.9/1.3	0.1	—	0.2	2.0/3.0	—	0.05[1]

NOTE: Where single units are shown, these indicate the maximum amount permitted.
[1] *Each.*
[2] *If iron content exceeds 0.4%, it is desirable to have manganese present in amount equal to ½ the iron.*

Adapted from "Standards for Aluminum Casting Alloys" by F. H. Smith, Light Metals, January 1954, p. 17.

◀ **For more information, Circle No. 301**

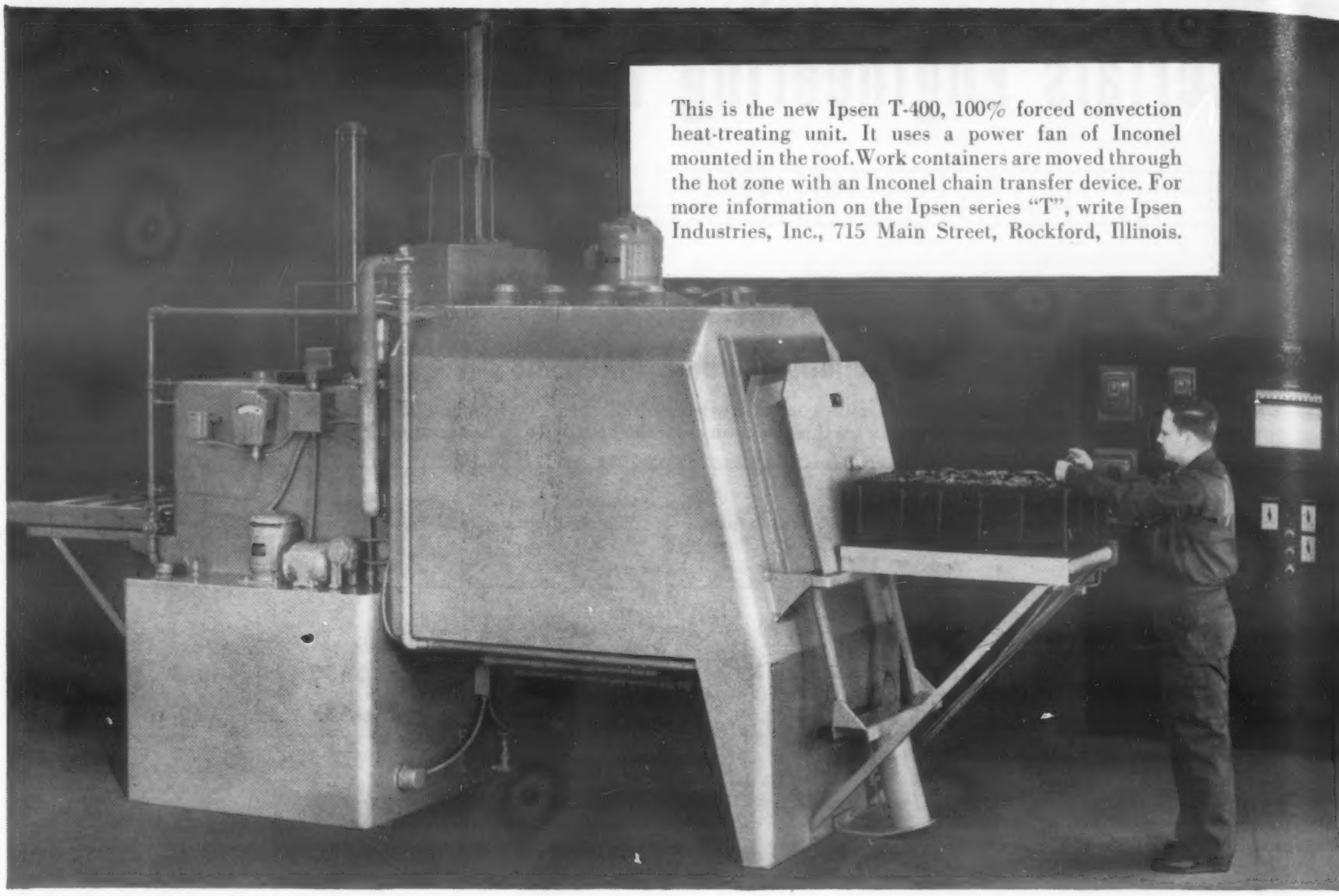
A Materials Data Sheet

Phenolic Molding Materials

Phenolic molding materials are made from phenolic resins combined with various fillers. By selection of resin and filler they can be fitted to a wide variety of applications. These materials are thermo-setting and can be molded in compression, transfer or plunger molds.

Type	ASTM Test Method	General Purpose Cellulose Filled Type 2	General Purpose Improved Shock Resistance Type 3	Shock Resistance Flock, Paper, or Pulp Filled Type 12	Shock Resistance Fabric Filled Type 4
PHYSICAL PROPERTIES					
Specific Gravity	D792	1.32–1.55	1.32–1.45	1.34–1.46	1.34–1.46
Thermal Cond, Btu/Hr/Sq Ft/Ft/F	C177	0.1–0.16	0.1–0.16	0.1–0.16	—
Coef of Exp per F	D696	$1.6–2.3 \times 10^{-5}$	$1.6–2.3 \times 10^{-5}$	$1.6–2.3 \times 10^{-5}$	$1.6–2.2 \times 10^{-5}$
Specific Heat Btu/Lb/F	—	0.35–0.40	—	—	—
Water Absorption, 24 hr %	L570	0.3–0.8	0.3–0.8	0.4–1.5	0.4–1.5
MECHANICAL PROPERTIES					
Mod of Elast in Tension, Psi	D638	$8–12 \times 10^5$	$8–12 \times 10^5$	$8–12 \times 10^5$	$9–13 \times 10^5$
Tensile Str, Psi	D651	6500–8500	5600–8500	5000–8500	5000–8500
Hardness, Rockwell	D785	M110–120	M108–120	M100–120	M93–120
Impact Str, Izod Notched (Ft-Lb per in. of notch)	D256	0.24–0.34	0.32–0.50	0.46–0.90	0.75–2.0
Mod of Elast in Flexure, Psi	D790	$8–12 \times 10^5$	$8–12 \times 10^5$	$8–12 \times 10^5$	$9–13 \times 10^5$
Flexural Str, Psi	D790	8500–12,000	8500–11,500	8000–11,500	8000–12,000
Compressive Str, Psi	D695	24,000–36,000	23,000–35,000	24,000–35,000	20,000–30,000
ELECTRICAL PROPERTIES					
Elect Res, Ohm-Cm (Volume)	D257	$1–100 \times 10^{11}$	$0.01–10 \times 10^{11}$	$1–50 \times 10^{11}$	$0.4–10 \times 10^{11}$
Dielectric Str (Short Time) Volts/mil	D149	200–425	240–350	250–350	200–365
Dielectric Constant					
60 cycles	D150	5.0–9.0	6.0–9.0	5.6–11.0	6.5–15.0
1,000,000 cycles	D150	4.0–7.0	4.5–7.0	4.5–7.0	4.5–7.0
Loss Factor					
60 cycles	D150	0.25–2.7	0.48–1.4	0.48–3.9	0.52–4.5
1,000,000 cycles	D150	0.12–0.5	0.14–0.4	0.14–0.4	0.14–0.5
FABRICATING PROPERTIES					
Compression Ratio (Bulk Factor)		2.1–2.7	2.6–4.4	2.3–5.7	2.8–11
Compression Molding Temp, F	D958	290–380	290–380	290–380	290–380
Compression Molding Pressure, Psi	D833	1500–5000	2000–5000	2000–5000	2000–6000
Transfer Molding Temp, F	D958	275–340	275–340	275–340	275–340
Transfer Molding Pressure, Psi	D833	2000–10,000	2000–10,000	2000–10,000	2000–12,000
MAXIMUM RECOMMENDED SERVICE TEMPERATURE F		300–350	300	300	250–275
CORROSION RESISTANCE		Severely attacked by strong acids and strong alkalies. Effects of dilute acids, alkalies and organic solvents varies with the reagent. Chemical resistance varies with the particular formulation and not all materials of a type are equally resistant.			
USES		Mechanical applications include, pulleys, wheels, motor housings, handles; electrical uses include coil forms, ignition parts, condenser housings, fuse blocks, instrument panels; thermal applications include handles and appliance connector plugs; chemical uses include photographic development tanks, rayon spinning buckets and parts, milking machine cups; decorative applications include radio and television cabinets, handles, knobs, buttons.			

(Continued on next page)



Ipsen puts Inconel in 5 hot spots

in their new T-400

Hot endothermic gases are blasted through Ipsen Industries' new T-400 heat-treating unit by a powerful fan mounted in the furnace roof.

That fan is the *number one spot* where Ipsen specified Inconel for resistance to oxidation, carburization, high temperature corrosion and strength at high temperatures.

The furnace, which handles 400 pounds per hour automatically, is a straight-through design. Its Inconel trays (number two spot) are moved from the heating zone to the quench zone by a patented Ipsen cold-chain transfer of high strength Inconel (number three spot).

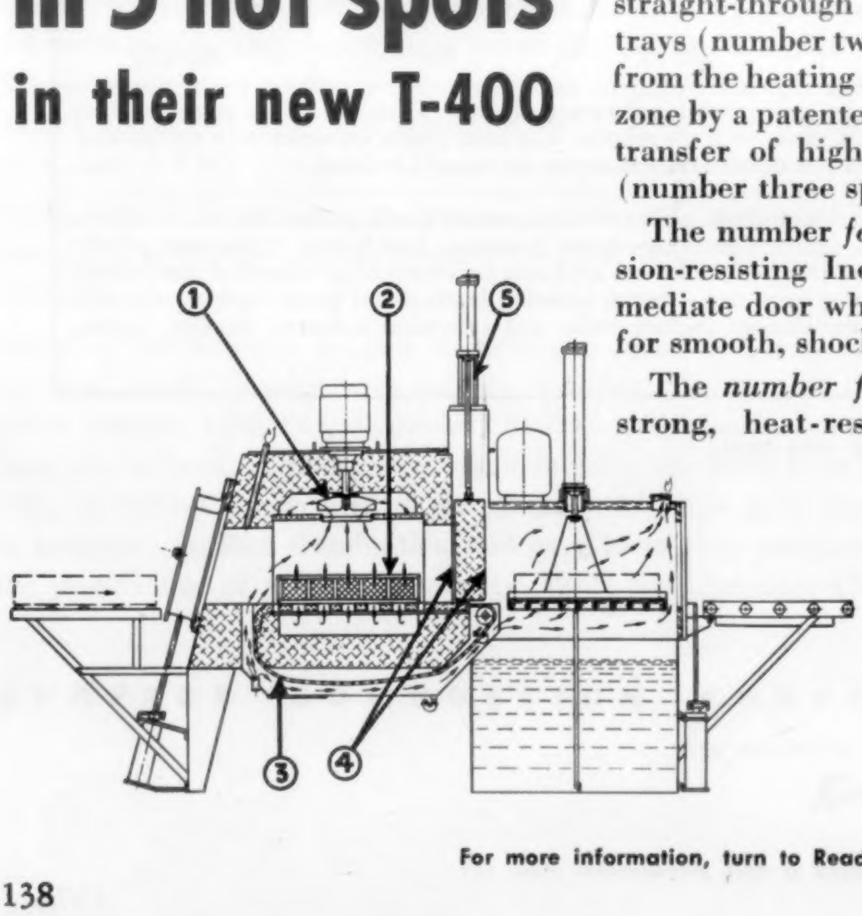
The number *four spot* for corrosion-resisting Inconel is the intermediate door which is air-powered for smooth, shockless operation.

The *number five* application of strong, heat-resisting Inconel is the shaft of the intermediate door cylinder.

It's no wonder Ipsen specified Inconel when you realize that many furnace users have reported extra long service life from Inconel equipment operating in temperatures as high as 2,100° F.

You can get this same long life in your furnace parts and heat-treating equipment. You'll find that Inconel can be readily shaped and welded to fit any practical design for fabricated equipment. It is produced in all the common mill forms, including a "T" section.

If you need advice on high temperature problems, Inco's High Temperature Engineering Service will be glad to help. Write them. And ask for a copy of the High Temperature Work Sheet to help you outline your problem.



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Inco Nickel Alloys

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"S"® MONEL • INCONEL® • INCONEL "X"® • INCONEL "W"®
INCOLOY® • NIMONIC® ALLOYS • NICKEL
LOW CARBON NICKEL • DURANICKEL®

For more information, turn to Reader Service Card, Circle No. 481

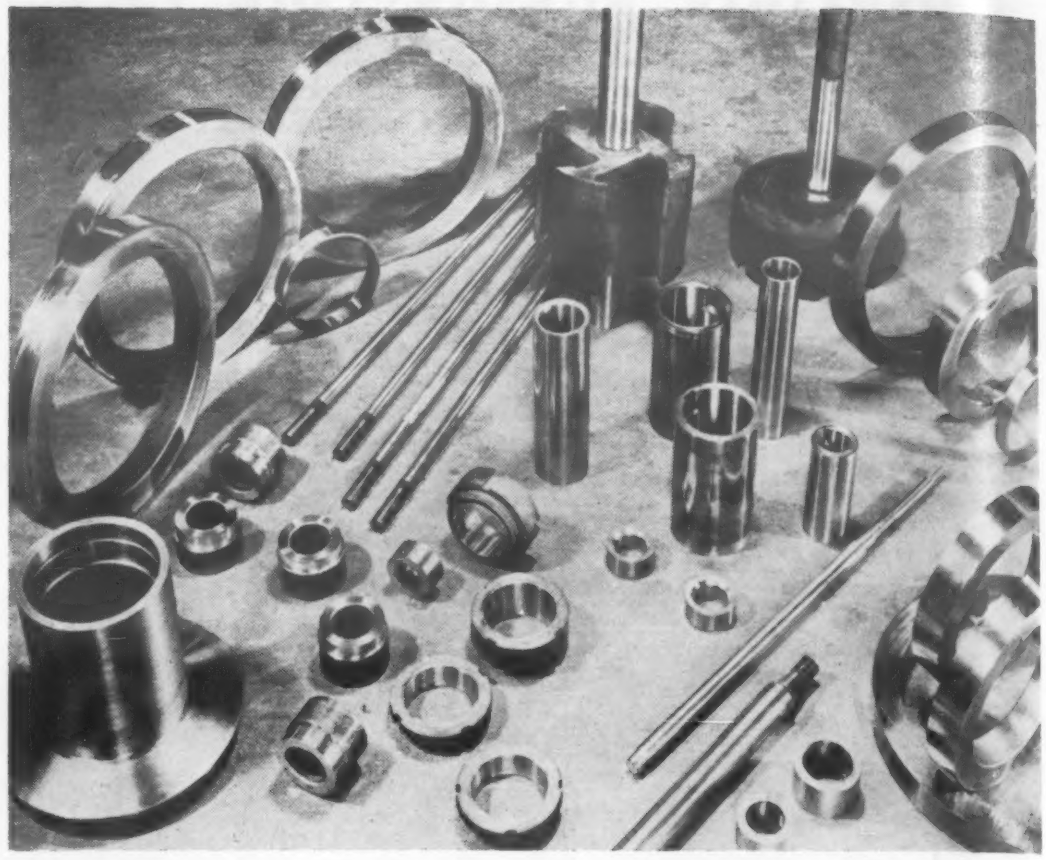
Phenolic Molding Materials—Continued

Type	ASTM Test Method	High Shock Resistance Fabric Filled Type 5	Very High Shock Resistance Cord Filled Type 6	High Frequency Insulation Type 7	Superior High Frequency Insulation Mineral Filled Type 8
PHYSICAL PROPERTIES					
Specific Gravity	D792	1.36–1.43	1.36–1.41	1.37–1.95	1.75–1.92
Thermal Cond, Btu/Hr/Sq Ft/Ft/F	C177	—	—	0.24–0.34	0.24–0.34
Coef of Exp per F	D696	—	—	1.0×10^{-5}	1.0×10^{-5}
Specific Heat Btu/Lb/F		—	—	0.28–0.32	0.28–0.32
Water Absorption, 24 hr %	L570	0.5–1.75	0.8–1.75	0.03–0.10	0.01–0.07
MECHANICAL PROPERTIES					
Mod of Elast in Tension, Psi	D638	$9–13 \times 10^5$	$9–13 \times 10^5$	$30–40 \times 10^5$	$30–50 \times 10^5$
Tensile Str, Psi	D651	6000–9000	6000–9000	5000–7000	5000–7000
Hardness, Rockwell	D785	M104–120	M100–120	M100–110	M100–110
Impact Str, Izod Notched (Ft-Lb per in. of notch)	D256	2.0–4.4	4.0–8.0	0.30–0.36	0.30–0.38
Mod of Elast in Flexure, Psi	D790	$9–13 \times 10^5$	$9–13 \times 10^5$	$30–40 \times 10^5$	$30–40 \times 10^5$
Flexural Str, Psi	D790	9500–14,000	8500–15,000	8000–12,000	8000–12,000
Compressive Str, Psi	D695	20,000–30,000	15,000–24,000	15,000–24,000	15,000–25,000
ELECTRICAL PROPERTIES					
Elect Res, Ohm-Cm (Volume)	D257	$1–10 \times 10^{11}$	$1–10 \times 10^{11}$	10^{12}	10^{13}
Dielectric Str (Short Time) Volts/mil	D149	225–400	200–325	300–450	300–460
Dielectric Constant					
60 cycles	D150	6.5–15.0	7.0–10.0	5.0–7.5	4.7–5.5
1,000,000 cycles	D150	4.5–7.0	5.0–6.0	4.4–5.2	4.4–5.1
Loss Factor					
60 cycles	D150	0.52–6.8	0.7–3.1	0.1–0.5	0.05–0.3
1,000,000 cycles	D150	0.14–0.6	0.2–0.5	0.04–0.2	0.02–0.06
FABRICATING PROPERTIES					
Compression Ratio (Bulk Factor)		6–15	12–18	2.1–2.7	2.1–2.7
Compression Molding Temp, F	D958	290–380	280–380	300–350	300–350
Compression Molding Pressure, Psi	D833	2000–6500	2000–6500	2000–6000	2000–5500
Transfer Molding Temp, F	D958	275–340	275–340	275–325	275–325
Transfer Molding Pressure, Psi	D833	2000–12,000	2000–12,000	2000–10,000	2000–10,000
MAXIMUM RECOMMENDED SERVICE TEMPERATURE F		250	250	300	250–300
CORROSION RESISTANCE		Severely attacked by strong acids and strong alkalies. Effects of dilute acids, alkalies and organic solvents varies with the reagent. Chemical resistance varies with the particular formulation and not all materials of a type are equally resistant.			
USES		Mechanical applications include, pulleys, wheels, motor housings, handles; electrical uses include coil forms, ignition parts, condenser housings, fuse blocks, instrument panels; thermal applications include handles and appliance connector plugs; chemical uses include photographic development tanks, rayon spinning buckets and parts, milking machine cups; decorative applications include radio and television cabinets, handles, knobs, buttons.			

Prepared with the assistance of the Manufacturing Chemists' Association, Inc.
Based on the Chemists' Association Publication "Technical Data on Plastics". 1952.

(To be continued in next issue)

For Severe Service . . .



These Precision Parts Were Surfaced With . . .

Quality Hard Facing

by JOHN WISCHHUSEN, Vice President, Cleveland Hard Facing Co., Inc.

The need in industry today for precision components to operate under severe conditions has called for refinement of hard facing by welding, both in materials and techniques.

● IN THE EARLY days of welding, the repair of worn equipment parts by building up a new surface at the point of wear was generally accomplished by arc welding with iron base alloys. In most of these cases a reasonable amount of crudeness in the final finish could be tolerated without complaint. In recent years, however, the need for improved techniques for hard surfacing has become evident, particularly when problems of high temperature, corrosion, and precision surfaces are superimposed on the basic requirement of durability.

Such requirements have been met in part by the use of weld metal, the total alloy content of which is made up of cobalt-chromium-tungsten,

commonly known as Stellites, and by other materials of high alloy content with less than 10% iron. These materials are applied today mainly by oxyacetylene torch welding, which requires skillful techniques because of the importance of holding interalloying between the base metal and the weld metal as low as possible. Careful torch handling is also important to overcome problems of shrinkage, cavitation, and thermal cracking.

Examples of such types of work where the higher efficiency requirements reach the critical stage are some internal combustion engines, heavy duty pumps, high pressure steam regulators, corrosion-resistant valves, intensive mixers, and extruders. Many of these parts employ a cobalt-chromium-tungsten overlay on various precision components to meet problems of high temperature, corrosion, precision surfaces, and high resistance to wear.

Factors Affecting Quality of Hard-Facing

To gain optimum results and a trouble-free welding operation on maintenance repair of worn equipment, it is most important to remove all foreign material from an area beyond the limits of the weld before the welding begins.

Grease, oil, chemicals, pits, burned metal, and heavy layers of oxides should be thoroughly removed from the base metal by scrubbing with solvents, rubbing with steel wool and by wire brushing or machining. On new components, a rough cut of 1/16 in. should be machined from critical areas that are to be hard faced.

The composition of the base metal greatly affects its weldability. Sulfur, phosphorous and selenium in Type 303 Stainless, and the aluminum content in hardenable nickel-copper alloys, are among the constituents that can decrease weldability. To overcome such difficulties, a flux should be applied before the welding begins.

High hardenability in certain martensitic steel alloys such as Type 410 Stainless and 14-4-1 die steels may also cause trouble. In such cases, annealing or drawing immediately after hard facing, modifies the hardness pick-up and prevents cracking.

Also to be considered is the formation of a tenacious oxide scale when melting some hard facing materials. Use of the inert arc method of application, which excludes atmospheric oxygen and gives a high localized temperature is recommended to overcome such scale formation. This method may also be employed when certain non-ferrous materials, such as copper, are to be surfaced.

Finishing the Surface

After the hard surface material is applied, it is customary to rough machine the overlay, leaving enough stock for a finish machining operation. This rough machining affords a fast method of removing excess material and also is an aid to inspection for porosity, cracking, or low spots, which can then be rewelded before finish grinding.

A heavy cut is preferred to prevent a burnishing action by the cutting tool. Also by taking a large cut, any tendency to "chatter" is minimized since the tool cuts beneath the level at which there would be high and low spots possibly causing tool vibration. The use of coolants when maching is recommended on a production set-up only where high cutting speeds and form tools are employed.

Considering Automation

Using semi-automatic methods for applying hard facing creates advantages and also problems, though the latter are not unreasonably difficult to solve.

In Fig 2 a single pass overlay four to five inches wide can be seen around each end of the 6 in. dia "dumb-bell" parts. This overlay is quite smooth, and illustrates what can be expected when applying the hard facing by semi-automatic means.

In these cases, the cobalt-chromium-tungsten materials are best applied automatically with oxyacetylene. This is partly because the welding rods are furnished in a cast and uncoated form and are not applicable to a submerged arc technique. This mechanized application of the surface was accomplished by using a multiple rod, gravity-fed, welding head which oscillates while the part is turning on its axis.

Two multiple-tipped welding heads are needed; one to preheat the surface, the other for the welding and cut-off operation, with the rods melting as they are "wetted" into the surface of the base metal.

By employing the proper number of rods with the correct horizontal oscillation cycle, it was further possible to obtain an overhang at the edge, which was a requirement in this instance. This overhang was also retouched by hand welding to put it at the proper adjustment.

(Continued on next page)

Quality Hard Facing

continued from page 141

Typical hard faced parts before final machining and grinding.

This form of automatic deposition is also used for wide, long lineal deposits for wear strips and shear blade applications. While extra amounts of oxyacetylene are consumed by the automatic method, the increased costs of it are more than offset by the economies resulting from the increased rate at which the alloys are deposited.

A limitation of such a method is the impracticability of interrupting the welding operation for any purpose. Accordingly, it is important for the base material to have a uniform weldability in order to insure an uninterrupted and consistent deposition.

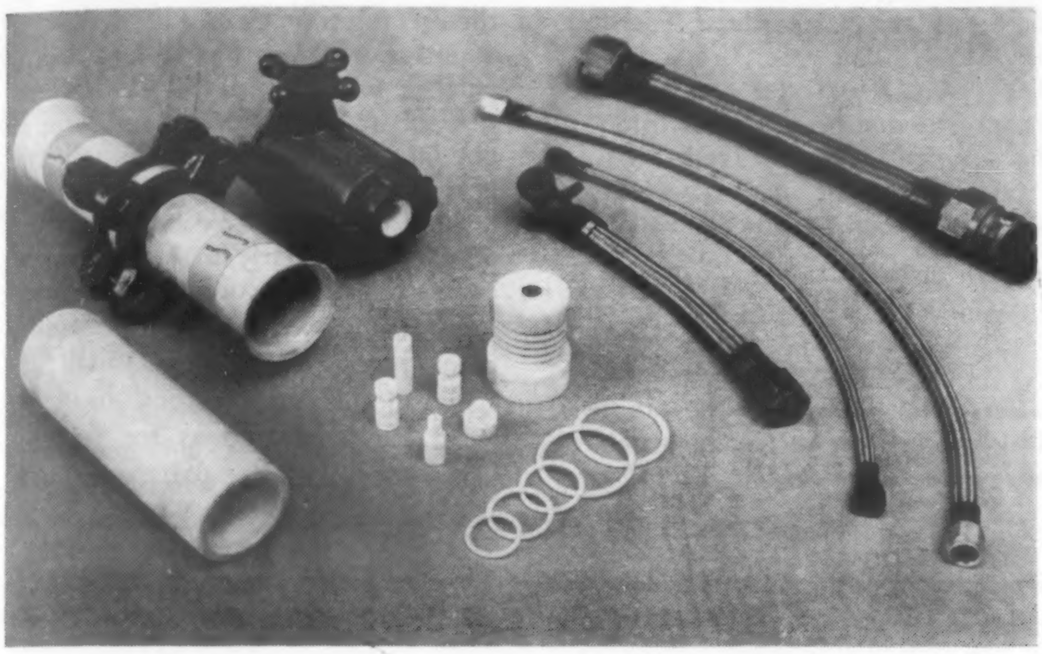
Alternate Method

Other means of mechanization are accomplished by rotating parts in a vertical position beneath the welding head. With this technique the rod can be fed either by gravity or by puddling. Puddling is the most common method when the purpose is to fill a groove with weld metal.

Since the demand for hard faced surfaces suitable to overcome the various problems is steadily increasing at the same time that the requirements become more exacting, it is important for the technician to develop parallel improvements in application techniques, while the metallurgist continues developing improved hard facing materials. In this way the problems of hard facing for high temperature, wear and corrosion service which are present at every stage—from surface preparation to final inspection—can be solved.

New Materials, Parts and Finishes

. . . and Related Equipment



Hose, hose assemblies, pipe and tubing are produced with the Teflon compound.

Reinforced Teflon Resists Severe Corrosive Conditions

Reinforced hose and pipe are now being produced, made of a modified Teflon compound that is said to minimize the unfavorable characteristics yet retain the advantageous qualities of the fluorocarbon plastic. The product was developed by *Resistoflex Corp.,* Belleville, N. J., to handle highly corrosive materials at severe temperatures.

Fluoroflex-T R-500 hose is made of the company's compound, Fluoroflex-T #1001, extruded in a seamless tube and reinforced with a braided jacket of stainless steel wire. This hose, coupled with high strength steel fittings becomes R-3800 hose assemblies, designed for high temperature aircraft and jet engine service. Aluminum fittings are provided where light weight is the primary objective.

Fluoroflex-T laminated pipe is made of the fluorocarbon compound reinforced with Teflon-coated glass fabric. It is light weight, non-fragile, and can be cut and fitted on the job with the aid of a portable heated flaring tool. In order to allow the installation of complete piping systems, a line of corrosion-proof pipe fittings has been developed, including elbows, reducers and adapters.

Inherent Qualities of Teflon

Teflon has one basic weakness: a poor mechanical structure which is revealed in a low tensile strength, porous micro structure and a tendency to flow under pressure. It also exhibits a high coefficient of thermal expansion, a factor that can either be advantageous or limiting, depending on the applications. The cause of the structural deficiencies has been found to lie mainly in the methods of converting the powdered resin to solid forms. The material cannot be melted like most plastics, but must be formed by a compacting and sintering operation, which results in products with wide variations in physical and electrical properties.

According to the Resistoflex Corp., their modified compound #1001 minimizes these structural drawbacks, and the resultant product has a greatly improved tensile strength, homogeneity and freedom from stress.

The advantages of the fluorocarbon for this application lie in 1) its virtually complete chemical inertness, the only materials known to attack it being molten alkali metals and chlorine trifluoride; 2) its wide useful temperature range of approximately —100 to over 500 F; 3) its dielectric strength of 400+ v per mil and a power factor of 0.0005; and 4) its low coefficient of friction due to its "abhesive" characteristics.

Applications and Sizes Available

The combination of properties mentioned above indicate that the new product may find a multitude of uses in aircraft manufacture due to the need for tubing and pipe to carry the highly active fuels and lubricating oils which must at times reach temperatures in the 400 F range. Applications should also be found in guided missile work where chemical attack exists to an even greater degree because of the highly active nature of the fuels and oxidizers used.

In addition to these specialized applications, the company anticipates a wide range of usefulness in the chemical processing industries, including fine and heavy chemicals, petrochemicals, pharmaceuticals, foods and beverages.

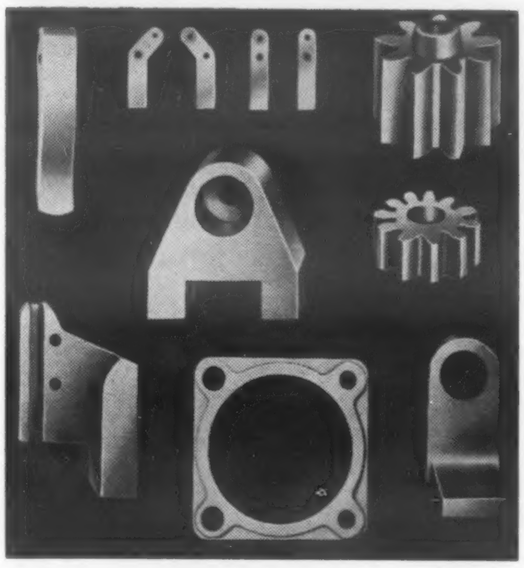
The R-500 hose is designed for a working pressure of 1000 psi, and is available now in sizes from 1/4 to 1 in. dia; 1 1/4 to 1 1/2 in. sizes will be available in the latter part of this year.

The laminated pipe is available in the following dia sizes and burst pressures: 1 in.—1600 psi; 1 1/2 in.—1100 psi; 2 in.—700 psi; 3 in.—500 psi; 4 in.—400 psi.

(Continued on next page)

New Materials, Parts and Finishes continued

18:8 Stainless Steel Powder



Powder metal shapes compacted with Stain-Alloy are said to be less susceptible to intergranular corrosion.

An 18:8 low carbon, moldable stainless steel powder, now being marketed by *Alloy Metal Powders, Inc.*, 238 Eagle St., Brooklyn 22, N.Y. is said to offer increased resistance to intergranular corrosion of the sintered compact. Trade marked "Stain-Alloy", the material is said to be a free-flowing powder, all particles of which pass through 150 mesh and approximately 60% of them being finer than 325 mesh.

The powder is moldable at compacting pressures of 30 to 50 tons per sq. in. and effective sintering is obtained at 2100 F with normal sintering times.

The company recommends the powder particularly to fabricators of gears, television cores, self-lubricating bearings, welding alloys, metallic paint, porous metal filters, small precision mechanical electronic and electrical parts, as well as for conventional metal powder parts.

New Adhesives Join a Variety of Materials

Five new adhesives recently marketed offer bonds for a variety of materials from paper to metals and plastics, and include a wide range of resistance to temperature and peeling.

Bonds Cellulose Tri-Acetate Film and Paper Stock

Two adhesives developed by the *Polymer Industries, Inc.*, 284 Sheffield ave., Brooklyn, N.Y., are now available: Polybond G-1028 for bonding cellulose tri-acetate films and Polybond K-393 for joining all kinds of paper stock. Development of the adhesives was spurred by the needs of the packaging, publishing, and safety film industries, according to the company. Both are said to be machinable on standard adhesive equipment.

Polybond G-1028 is commercially odor-free and transparent and will bond high acetyl film to such non-porous surfaces as metal foils, plain tissue or coated cellophane, polyester film, pliofilm, polyethylene, nylon and teflon, as well as porous stocks such as cloth, paper, asbestos and mica. The adhesive is said to possess resistance to temperatures (in the range of —20 to 300 F), oils, water, ozone, and weak acids and bases.

Polybond K-393, designed for bonding paper stock, is odor free, heat resistant and possesses a fiber tearing bond.

Bonds Wood and Fabrics

A rubber latex adhesive, developed by *Industrial Products Div. of the Flintkote Co.*, 30 Rockefeller Plaza, New York 20, is said to bond wood, wood fiber board, felts, fabrics and other porous and semi-porous materials. It offers an advantage in being pressure sensitive to another film of the adhesive, though not to uncoated surfaces. This feature allows the coating of two surfaces, followed by a delay of up to a month before joining.

Called Flintkote Syntex L-852, the material is said to provide a firm and flexible bond over a temperature range of —10 to 150 F, with good moisture resistance provided the contact with water is not constant. A water base adhesive, it is non-flammable during application, may be applied by brush, spray or flow gun, and dries in about 1 hr to a brown color.

Bonds Masonry, Metal and Wood

Placco 1000, developed by the *Pioneer Latex and Chemical Co.*, Lincoln Blvd., Middlesex, N.J., is said to be a quick setting, heavy bodied, rubbery material which forms bonds which are waterproof, heat resistant (to around 300 F), non-flammable, non-toxic, and will not contaminate foodstuffs. A 2-sq in. bond of the material is said to have withstood a pull of more than 300 lb at temperatures above 300 F.

Among its applications in bonding to wood, masonry and metal are such items as hangers for wire, pipe and conduits, nailing strips, wallboards and flooring materials.

Bonds Metal, Nylon and Glass

A thermosetting industrial adhesive, Phenoweld is said to provide firm bonds for metal to metal and metal to nylon, as well as aluminum, steel, brass, copper, glass and nylon adhesions.

Developed by *H. V. Hardman Co., Inc.*, Belleville, N.J., Phenoweld is said to be applicable, in solvent solution, by brush, spray or dip methods, and when the solvent is evaporated, the adhesive is tack free. The parts to be assembled are then held together with only gentle pressure required. Where a high degree of chemical and solvent resistance is required, heat may be applied during bonding of the parts.

Phenoweld is said to have high electrical insulation properties which have caused it to be used successfully in making loud speakers, electronic coils and wiring equipment.

Epoxy Resin Combines Long Pot Life with Fast Cure

An epoxy type electrical insulation resin called Scotchcast No. 3 with a useable life of from three to five days before set-up has been marketed by *Minnesota Mining and Manufacturing Co.*, St. Paul, Minn.

This longer pot life offers certain production advantages to electrical manufacturers in that the resin may be mixed days ahead of time, and in quantities that allow efficiencies of use. Yet the actual cure time for the resin is said to be from two to four hours at 250 F, with a longer cure at lower temperatures.

Typical applications for the material are for embedding resistors, unitized electronic circuits, pre-amps, torroids, and audio and power transformers hermetically sealed in a solid block of resin for trouble free operation under adverse conditions.

The material is said to possess high electrical and physical properties and low viscosity. According to the company, no chemical degradation occurs within the operating range of —65 to 250 F; it is resistant to acids, alkalies, solvents and oils, and adheres well to most metals, plastics and conductors.

Its electrical characteristics include a dielectric strength of from 1000 to 1500 v per mil on thin sections, a low dissipation factor over a wide temperature range at frequencies of 60 cycles to 30 meg, and a stable dielectric constant within this range.

High electrical and physical properties are claimed for this new epoxy casting resin.

Plastic-Copper Laminate Will Speed Printed Circuit Manufacture

A new material, Estoglas, consisting of laminated copper sheet and glass fiber reinforced polyester plastic sheet has been marketed by *Plastilight, Inc.*, 481 Canal St., Stamford, Conn. According to the company, the material offers physical and electrical properties which are superior to the paper-based phenolics, yet are lower priced.

The resin is an electrical-grade polyester with a filler of random mat glass fibers, giving uniform strength in all directions. Tensile and flexural strengths are said to be around 24,000 psi. Standard sheet size is 24 by 36 in., in various thicknesses from 0.044 in. up, and the plastic is clad on one or both sides with 1, 2, or 3-oz copper.

The bonding agent for the copper is said to provide surface electrical qualities equal to the base material. Dielectric strength is said to be 950 v per mil, power factor 0.55 at 10 kc, and a dielectric constant of 3.62 at 1000 cycles. After 24 hr at 90% relative humidity and 75 F, the decrease in these values is said to be approximately 10%.

Polystyrene Formulation Improves Flow Control

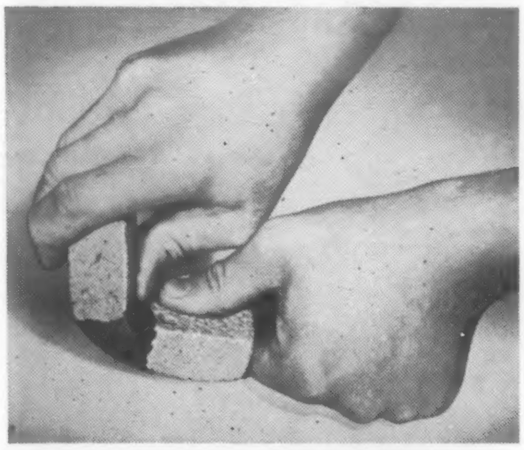
A new formulation of general purpose Styron (Dow polystyrene), developed by the *Dow Chemical Co.*, Midland, Mich., is said to provide molders with better control over the flow of the plastic in the mold.

The material, Styron 688, will flow faster and more evenly through the mold, offering advantages in injection molding of intricate or thin-walled parts or deep sections.

The material is expected to find applications in thin wall containers, vials and tubes, wall tile, back painted parts, large boxes and containers, honeycomb sections, and brush backs.

Styron 688 is available in crystal, transparent and opaque colors, and follows the same price schedule as Dow's general purpose polystyrene.

New Materials, Parts and Finishes



This flexibility plus a high quality bond is claimed for new sealing compound.

Rubber Compound Acts as Sealer and Expansion Joint

A new Thiokol-base compound, called PR-395-HT, is said to provide good service both as a sealer and expansion joint particularly in concrete repair work or original construction. The *Products Research Co.*, 3126 Los Feliz Blvd., Los Angeles 39, who developed it, recommends it for use wherever expansion, contraction or vibration requires joint resilience, by itself or in conjunction with a water seal.

The material is used with PR-1090 primer which is said to have high penetrating qualities, forming a waterproof barrier that prevents migration of moisture to the sealed surface.

Application of PR-395-HT can be made either with a spatula or extrusion gun since it has a non-sagging consistency and will hold its position on vertical and overhead installations.

It is said to have good weather resistance and retain its soft, elastic consistency indefinitely.

Dry Blending Vinyl Resin

A dry blending grade of vinyl resin has been added to the Pliovic line of polyvinyl chloride resins produced by the *Goodyear Tire & Rubber Co.'s Chemical Div.*, Akron, Ohio.

Called Pliovic DB80V, the properties of the resin allow plastic molders and extruders to obtain a free-flowing, dry mix without subjecting the blend to high heat and lengthy milling cycles on conventional mills.

The material is designed for economical production of such varied products as garden hose, wire insulation, refrigerator door gaskets and many other molded and extruded items.

Room Temperature Metal Cleaner

A metal surface cleaner which requires no heating coils and is adapted for use in hard water areas has been developed by *Klem Chemicals, Inc.*, Dearborn, Mich.

Klem K-A-T Cleaner is a combination of an alkali and emulsion and can be used for removing soils from both ferrous and non-ferrous metals. Maximum corrosion resistance and minimum surface etching are claimed for the product, as well as compatibility with paint solvents, allowing paint to be applied immediately after rinsing.

Titanium Bolts Now Available

Light-weight, high-strength titanium bolts of six types, primarily for use in airframe and aircraft engines are being manufactured by *Standard Pressed Steel Co.*, Jenkintown, Pa.

Because of titanium's high corrosion resistance in addition to its light weight, such fasteners are expected to be used in other industries such as the chemical industry.

The new bolts are available in two lines of flush head shear bolts, two lines of internal wrenching tension bolts, a line of external hexagon shear bolts and one of external wrenching tension bolts. Available sizes are No. 10—¼, 5/16, ⅜, 7/16, ½ and ⅝ in.

Dry Lubricant Tested at 800 F

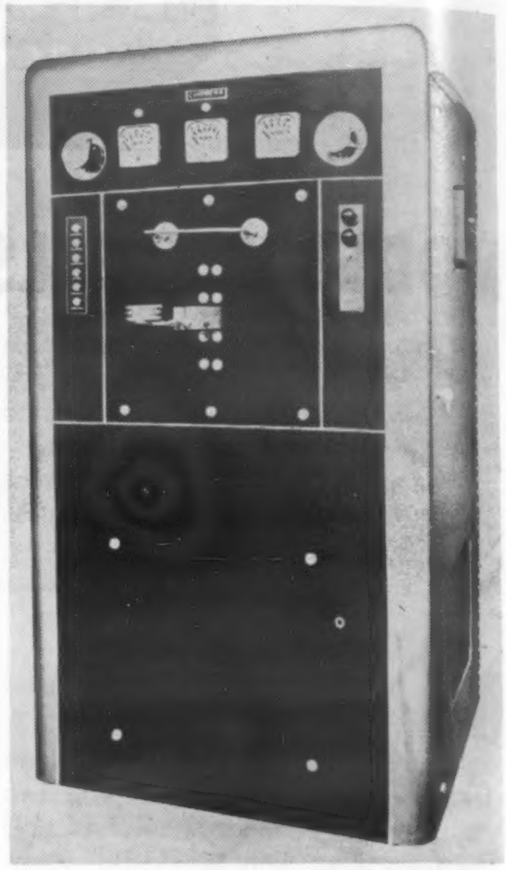
A solid film lubricant developed for operational temperatures of —60 to 1000 F is claimed by the *Everlube Corp.*, 6940 Farmdale Ave., North Hollywood, Calif.

The new lubricant is of a fused-on type and possesses proven lubricating qualities with liberal amount of flex, after exposure to 800 F.

It is said to be suited for use in high pressure steam units, in and around after-burners, and high temperature air valves. The Everlube Corp. maintains custom processing plants, or the lubricant may be applied by the manufacturer in his own plant with automatic equipment.

(Continued on page 150)

New Materials, Parts and Finishes



Redesigned Induction Heating Unit Offers Increased Efficiency

A redesigned 5 kw high frequency induction heating unit (Model LI-5A-1) for soldering, brazing and light heat treating applications is being manufactured by *Lindberg Engineering Co.,* 2450 W. Hubbard St., Chicago, Ill.

The main features of the new design are a heavier sheet steel cabinet, relocated indicating lights for easier observation, reduced cooling water consumption and molded porcelain water coils, eliminating rubber or organic tubing.

The steel cabinet is said to insure minimum R.F. radiation and to conform to FCC regulations. Interior steel partitions are provided to isolate oscillator, power and control components.

The redesigned water cooling system is said to eliminate moisture condensation on internal components as well as reduce water consumption. An electrical interlock system prevents the application of power when cooling water is not flowing, eliminating the danger of work coil burnouts.

Industrial type tubes are provided with constant voltage transformers to maintain proper tube filament voltage

values regardless of line voltage fluctuations.

Power input is 230/460 v, single phase, 60 cycles. Power consumption is 12.5 kva max at 90% power factor. Water consumption is 2-3 gal per min at max inlet temperature of 86 F.

Two New Welding Rods: One for Aluminum, One for Steel

A new rod designed for either torch or carbon arc welding of 3S, 14S, 43S, 52S, and 61S aluminum has been developed by *All-State Welding Alloys Co., Inc.*, 249-55 Ferris Ave., White Plains, N.Y.

The benefits claimed by the company through use of the rod are an increase in speed of application with no sacrifice of physical properties; sound, porosity-free welds; less distortion of work; and the flexibility in choice of either carbon arc or torch.

The rod will be marketed as All-State No. 35 F. C. Aluminum Rod (flux coated); it is 28 in. long in diameters of 3/32, 1/8, 5/32, and 3/16 in.

The *General Electric Co.'s Welding Div.*, Schenectady, N.Y., is now marketing a contact welding electrode which is said to provide increased welding speeds with mild and medium carbon steel. It is best suited for welding machinery, low pressure storage tanks and light structural work.

Encased in a rutile-type covering enriched with iron powder, the new electrode can be used effectively on horizontal and flat position fillets and laps, single and multiple pass butts, and deep grooves and cover passes on multiple-pass butt welds.

According to the company, since it is a contact type electrode, less physical effort is required to weld, and less skill required of the worker. In addition, 80% less spatter is reported with this type of electrode over other types.

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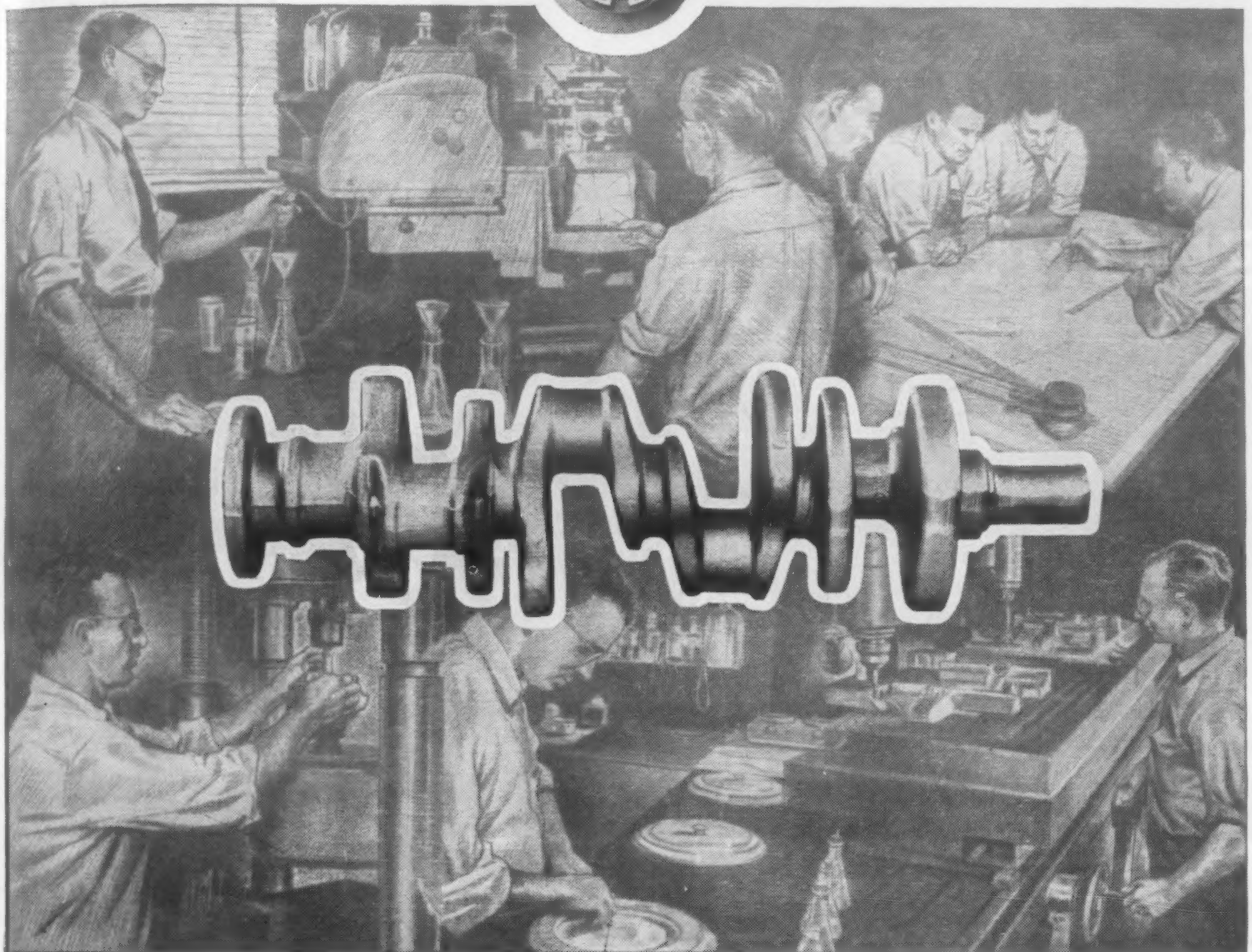

The crankshaft in the modern V-8 engine requires the ultimate in forging technique. Today's high compression engines, with continually increasing horsepower, further emphasize the importance of forging quality.

Wyman-Gordon technical know-how assures quality essential for maximum physical properties, uniform machinability and balance control . . . crankshaft forging specialists since the introduction of the internal combustion engine.

WYMAN-GORDON

Established 1883

FORGINGS OF ALUMINUM • MAGNESIUM • STEEL • TITANIUM

WORCESTER, MASSACHUSETTS

HARVEY, ILLINOIS DETROIT, MICHIGAN

For more information, turn to Reader Service Card, Circle No. 341

New Materials, Parts and Finishes

400 Amp D.C. Rectifier-Type Welder

A new 400 amp, three-phase, d.c., rectifier-type welder with a 60% duty cycle has been marketed by *General Electric Co.'s Welding Div.*, Schenectady, N.Y.

Designated as G-E Type WR40A, the new welder can be equipped to operate on two-phase power and has a current welding range of 70 to 500 amps. It can be utilized with a variety of electrode sizes for repair, maintenance and construction work.

A stepless current control simplifies current adjustments, and because of the high current produced by the six parallel-path selenium rectifiers in the new unit, stable arcs and smoother welds are said to be possible. Class H (silicone) insulation is said to give protection against high temperatures, moisture, fumes, and chemicals.

As additional protection for the coils and rectifier stacks, a reversible 14-in. forced-draft fan, rated for continuous service, provides ventilation and prevents hot spots. The cooling system operates on an updraft principle, taking cool air near the floor and preventing the recirculation of exhausted hot air that is continually rising. The life of rectifier stacks can be prolonged by means of the self-cleaning action obtained through reversing fan operation periodically.

The welder is operable on 220/440 v, reconnectable to either voltage. It is also available with full-time arc force control which is said to minimize popouts and freezing-in.

(Continued on next page)

New Materials, Parts and Finishes

Nickel Alloy Pipe for Highly Corrosive Uses

High nickel alloy pipe and tubing made by the Rockrite process (M&M, August, '50) is being marketed by *Stainless Welded Products, Inc.*, P.O. Box 406, 251 Cornelison Ave., Jersey City 2. It is available as Swepco Super Finished Pipe, and Swepco Cylinder Finished Tubing. The Cylinder Finish is said to be better than a honed surface and is suitable for use with soft packing without further grinding or machining, while the Super Finish Pipe is annealed, pickled and passivated after rocking.

Wall thickness tolerances are held to $\pm 5\%$ while diameter tolerances are as follows: Swepco Cylinder Finish i.d., $+0.000$, -0.008 to 0.010 in. depending on size; Swepco Super Finish o.d., ± 0.010 to 0.015 in. depending on size.

Uses for the product are found mainly in highly corrosive process lines and other applications calling for corrosion or contamination free lines. It is also used in bushings, couplings, gear parts, etc., where close tolerances are required.

Welded Pipe

Another product now being manufactured by this company is called Swepco Full Finish pipe, and is welded by the automatic inert-arc method. The welds are said to be sound, the pipe meeting ASTM specs A-269-47, A-312-51, and A-358, depending upon size. The pipe can be supplied in all the special alloys such as weldable stainless grades, high nickel alloys such as monel, nickel, inconel, Hastelloy alloys, Carpenter #20, titanium, etc.

The pipe is available in sizes of 2½ IPS and up, in Schedules 40 and 80, and in lengths up to 20 ft.

Silicone Enameled Magnet Wire for Hot Spot Applications

Intended for use in electrical equipment operating at "hot spot" temperatures of at least 266 F, a new silicone enameled magnet wire has been developed by *Anaconda Wire & Cable Co.*, Muskegon, Mich.

According to the company the

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have contributed greatly in making our performance possible"

says

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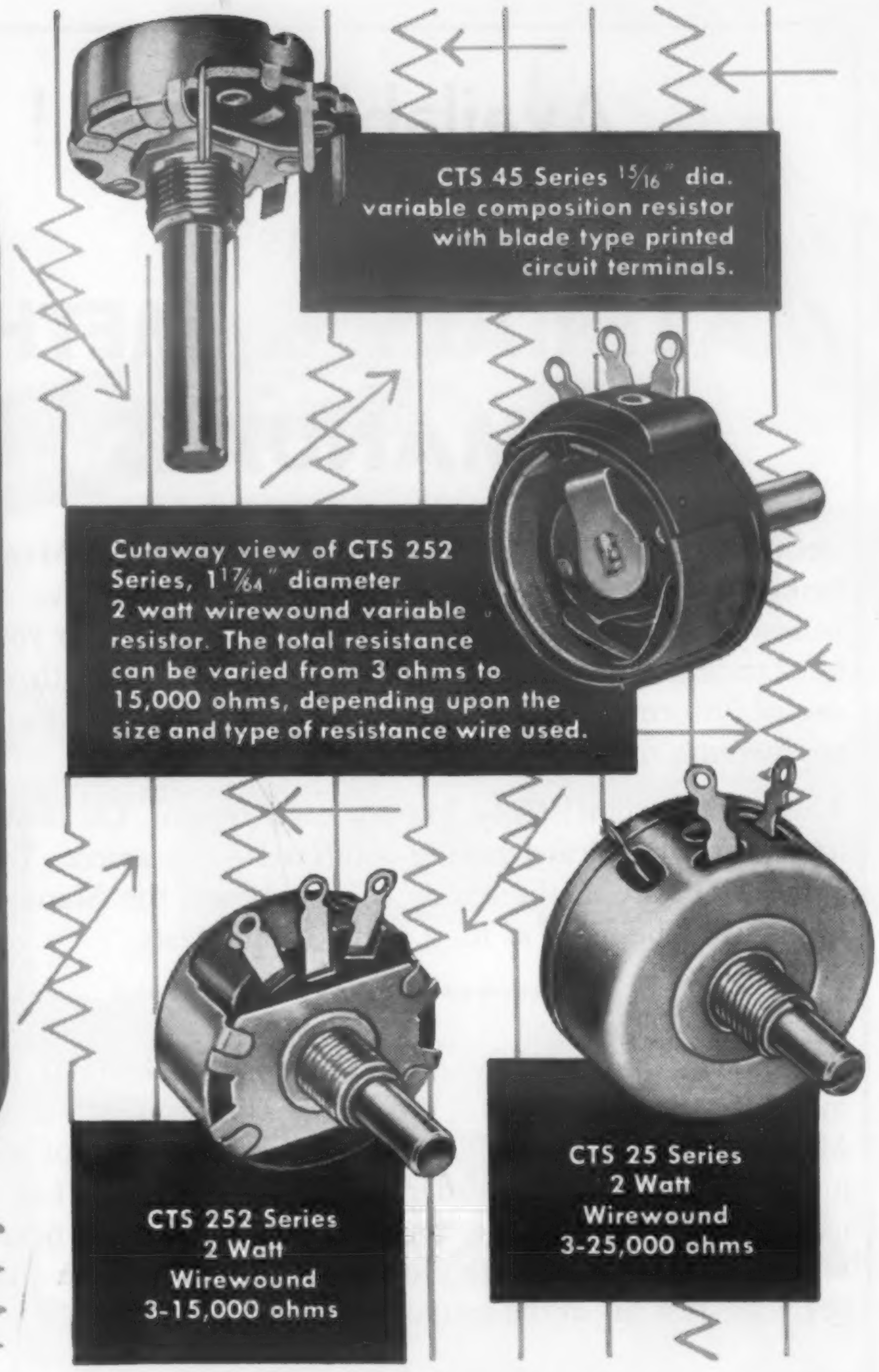

Chicago Telephone Supply Corporation has succeeded in accomplishing two things indeed difficult to combine, as summed up in their slogan "Specialists in Precision Mass Production of Variable Resistors." They manufacture the high quality variable resistors indispensable to radio, television, and military electronics. In fact, they are the world's largest producers of variable resistors.

To achieve this outstanding record, they concentrate their entire effort on variable resistors, they maintain close control over all manufacturing processes, and fabricate their own parts under close supervision from basic raw materials. Naturally, they make no secret of the importance to them of high quality materials.

States Chicago Telephone: "To make our raw material program effective, we have stressed the importance of dependable, quality-minded sources of supply. Driver-Harris is a supplier with these qualities, *and Driver-Harris alloys have contributed greatly in making our performance possible.* For many years we have been using Driver-Harris Nichrome*, Karma*, Advance*, and other D-H Alloy wires for our resistance windings, with excellent results. We can strongly endorse Driver-Harris' dependability and high quality products."

Nichrome, Advance, and Karma are at your service too, as are more than 80 other D-H alloys developed for application in the electrical and electronic fields. If a high degree of resistance and absolute uniformity of output are "musts" for *your* product, let us have your specifications. We'll be glad to make recommendations based on your specific requirements.

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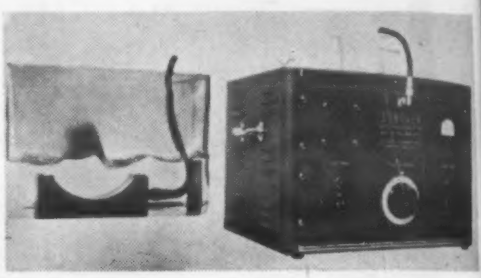
enamel has good abrasion resistance, adheres well to the conductor, is smooth, tough and is not attacked by common solvents. Also it will not crack when exposed to temperatures as low as —85F. The dielectric strength of the enamel is said to be 1500 v per mil.

Wire insulated with the enamel is available in single and heavy grades, in dimensions as quoted in Anaconda's General Catalog for Formvar and nylon. The film is removable with chemical strippers such as those used for Formvar, or by wire brush.



Ultrasonic Energy Speeds Parts Cleaning

An ultrasonic power generator and transducer, designed primarily for accelerating the cleaning and degreasing of small parts and metal objects such as strip, wire and tubing, as well as complex components, has been manufactured by *Branson Instruments, Inc.*, Stamford, Conn. The Sonogen Model 500 Ultrasonic-Power Generator functions by activation of the cleaning solvent in which is immersed the low voltage, focused, ceramic transducer.

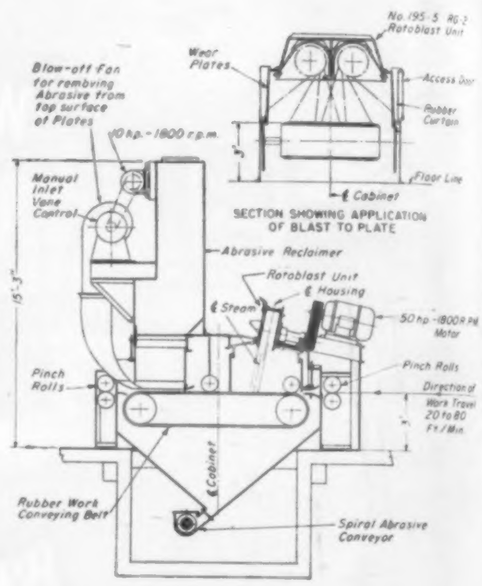
The radio-frequency output of the generator is 500 watts continuously at 450,000 cycles per sec. The transducer converts the R-F power to high-frequency mechanical vibrations which are transmitted through the solvent and shake dirt and grease loose from the work.

The transducers are sections of a 6-in. dia cylinder of barium titanate, with a surface of either 15 or 30 sq in. The concave cylindrical source concentrates the energy in a focal region where the cleaning action reaches optimum intensity.

For multi-stage cleaning, single Model 500 Generator can power several small transducers with a total surface area not exceeding 30 sq in.,

New Materials, Parts and Finishes

and when electrically conductive solvents must be used, special vessels with thin stainless steel bottoms are available to isolate the solvent from the non-conductive fluid in which the transducer is placed.



Automatic Blasting Machine Speeds Sheet Steel Finishing

The Rotoblast ES-503 machine designed for cleaning steel sheet and plate up to 54 in. in width at a production rate of 20 to 80 linear ft per min has been marketed by the *Pangborn Corp.*, Hagerstown, Md.

According to the company, the machine provides a fast method of imparting a good surface to sheet steel, better bonding surface for paint, and cost reduction through use of hot rolled rather than cold rolled sheet. The unit is said to be capable of cleaning in excess of 200 sq ft of surface per min. The two Rotoblast wheels throw 160,000 lb of abrasive per hr.

The machine takes the steel sheet or plate into the blast chamber automatically, blasts its surface, and removes all abrasive from the work before discharging it. A spiral conveyor carries the used abrasive to the elevator which carries it through the abrasive separator and reclaimer for recycling.

Standard equipment for the unit are two 195-5 wide vane wheels, each powered by a 50 hp, 1800 rpm motor.

(Continued on next page)

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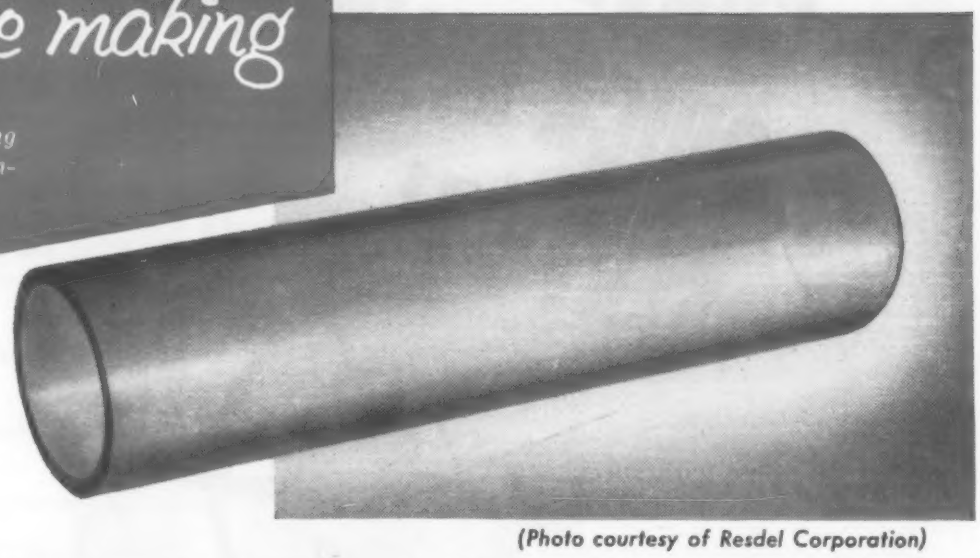
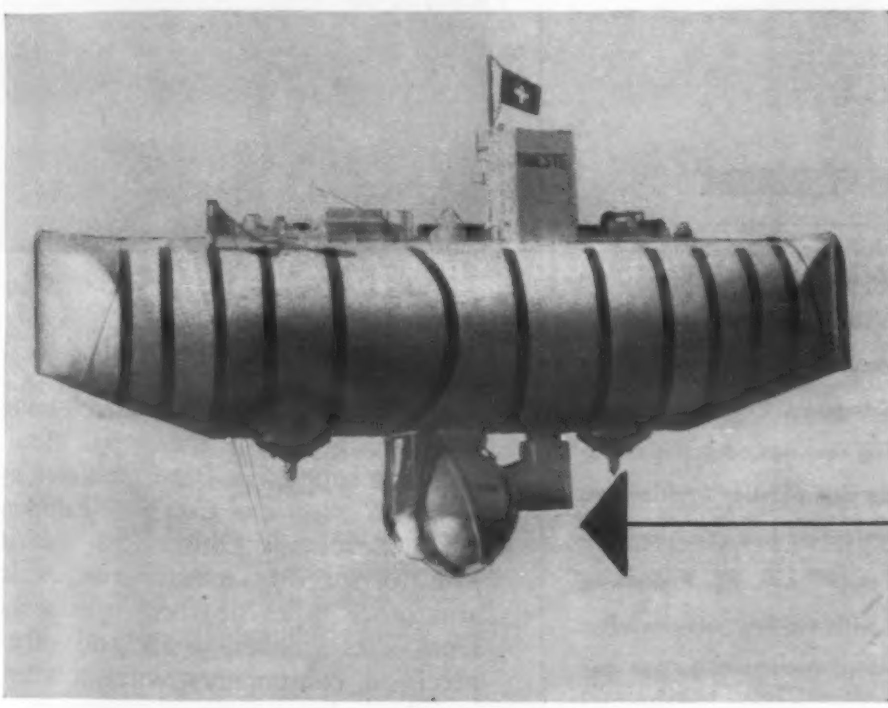


(Photo courtesy of Resdel Corporation)

ARALDITE RESINS USED TO MAKE CENTRIFUGAL CAST PIPE WITH EXCEPTIONAL PROPERTIES

Araldite Resins of the "CN" series are formulated especially for casting, potting, impregnating and encapsulating uses. The pipe shown here is available in a wide range of gauges, diameters and lengths. In addition to exceptional toughness, impact and dielectric strength, it offers excellent resistance to chemical attack from circulating corrosive liquids. Araldite cast pipe of larger diameters with sealed ends is used for storage of chemicals as well. The strong clean pipe is also undergoing tests for supportive structural uses. Araldite Resins of this type achieve outstanding results in castings bonded to metal parts, impregnating of transformers, capacitators, coils, motor windings and other electrical apparatus.



POWER CABLE INSTALLATION PROBLEM SOLVED EFFECTIVELY WITH ARALDITE RESINS IN "BATHYSPHERE" FOR RECORD-SHATTERING DESCENT

On this newest "Bathysphere" the controls are connected by instrument and power cables which pass through the wall of the cabin to the apparatus located outside the cabin. In the previous "Bathysphere" all motors were controlled through relay circuits. The relays were installed outside the cabin and only small wires were able to pass through the walls. By sealing the openings with Araldite Resins it became possible to simplify the arrangement and put full-sized power cables carrying currents up to 200 amperes through the walls. The Araldite Resin used was simply poured into the space between the walls of the sphere and the cables, where it hardened and formed a seal capable of withstanding the tremendous pressure of the water at the great depth of more than 4,000 meters below the surface of the Mediterranean to which the "Bathysphere" recently descended.

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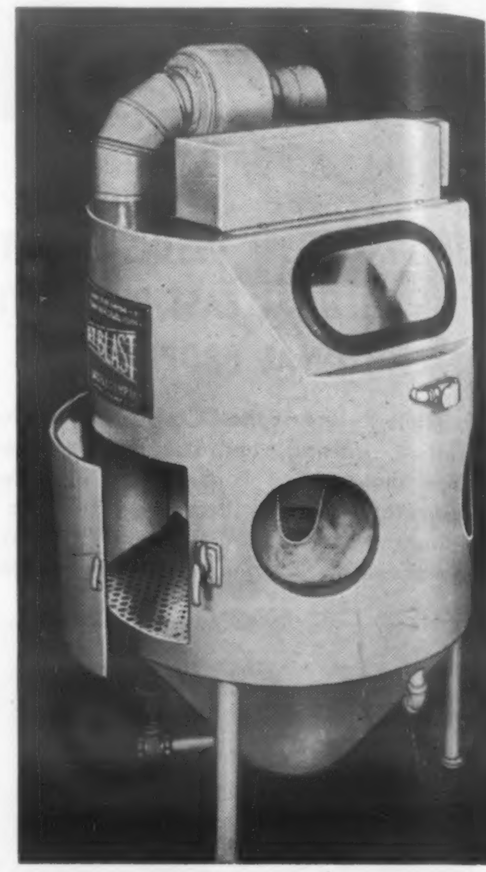


Bench Model Blasting Unit

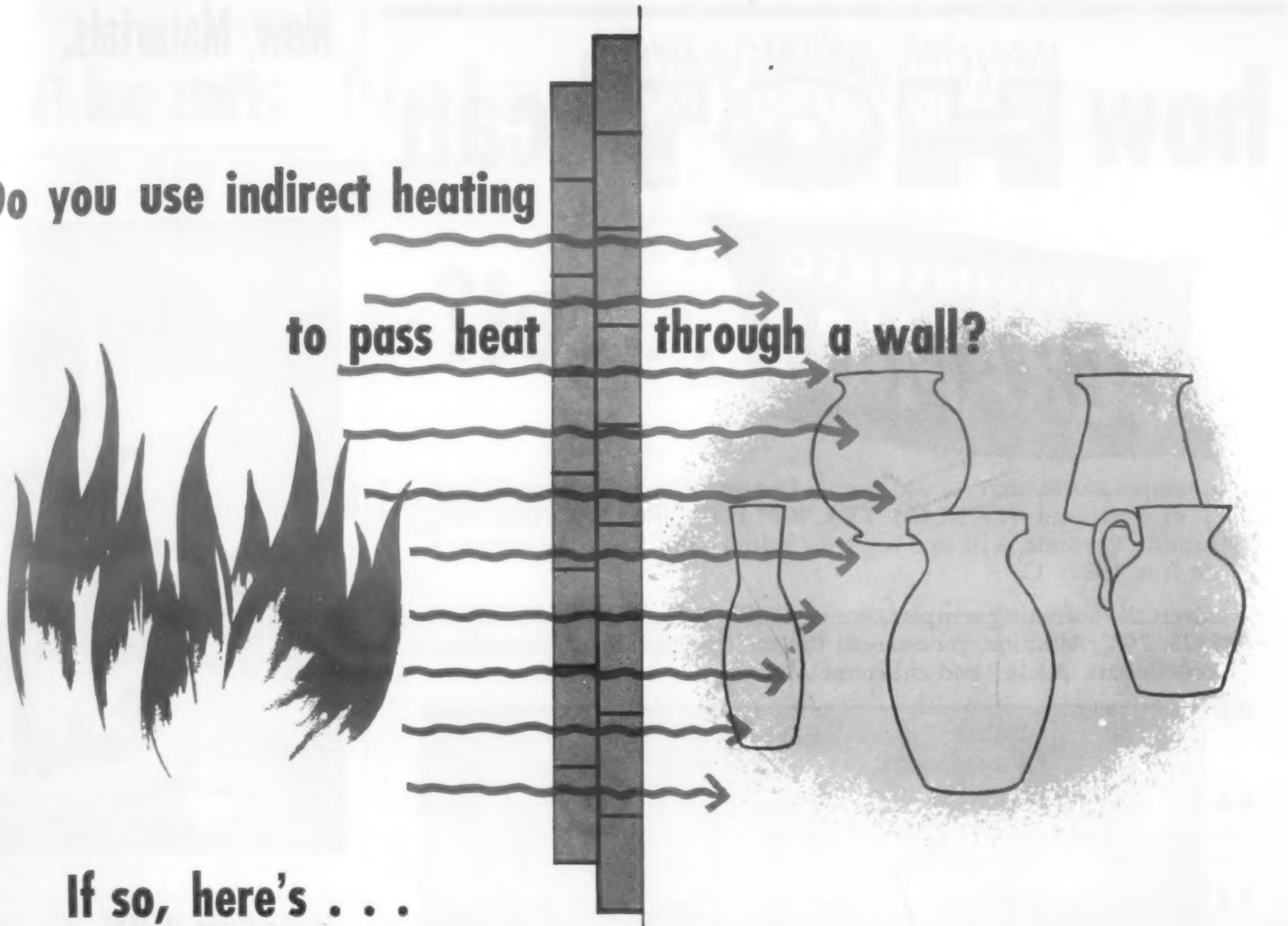
A Bench Model Jet Blast cleaning unit, designed for the small metalworking shops, has been marketed by *R. W. Renton and Co.*, 877 Addison Rd., Cleveland, Ohio. The unit is said to speedily remove rust, scale and other types of foreign deposits from dies, molds, tools and other precision components without altering their dimensions.

The Jet Blast method employs fine abrasive particles suspended in liquid. This slurry is picked up by siphon injection and propelled to blast proportions by means of a high velocity air stream. The blast of wet abrasive, when directed upon a surface, imparts a cleaning and polishing action, leaving a clean matte surface which offers good adherence and bonding qualities for paint, porcelain, rubber and many other materials.

The unit is 24 in. in dia, 43 in. high and weighs 155 lb. One or two blast guns may be used with 28 to 42 cu ft of air per min at a pressure of 85 to 100 psi. Liquid capacity is two gal and the abrasive capacity is 13 lb.

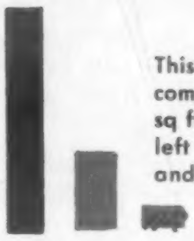
(Continued on next page)

Do you use indirect heating to pass heat through a wall?



If so, here's . . .

A refractory that's "heat-transparent"



This is how three commonly used refractories compare in thermal conductivity, (BTU/hr, sq ft and °F/in. of thickness at 2200 F). From left to right: silicon carbide, aluminum oxide, and fireclay.

While you ordinarily think of a refractory as a heat-*containing* material, CARBORUNDUM's silicon carbide is anything but. It actually transmits heat *11 times faster* than fireclay. Practically as fast as the high temperature alloys!

This property is silicon carbide's greatest asset. It makes it ideal for retorts, muffles, and hearths . . . or wherever you pass heat through a wall. Take one case: When used to replace the fireclay arch of a Mannhiem furnace, output was doubled—and the fuel input ratio was cut 50%! And that's not an exaggerated example.

This same property enables silicon carbide to absorb and release *up to five times as many BTU's* per second as fireclay. It's ideal for checkers, recuperators, and other heat-exchange equipment. On the other hand, it's equally good where heat has to be dissipated (e.g. arc shields, pot settings, etc.)

But the clinching advantages are that it has a tested crushing strength of over 10,000 psi at 2500 F . . . is safe to use up to 3000 F . . . withstands abrasive/erosive wear-and-tear far better than metals . . . is inert to acid attack . . . and, in general, outlasts other materials, even under the most destructive conditions known.

In fact, this ability to withstand extreme conditions distinguishes *all* CARBORUNDUM's super refractories (including one of the best *insulating* materials for high temperature work). These range all the way from a cotton-like ceramic fiber to super-dense refractories that are cast like metals. So whether you need to conduct heat, or contain it, CARBORUNDUM's "man-made minerals" offer unusual possibilities. We'd like to explore their interesting features with you.

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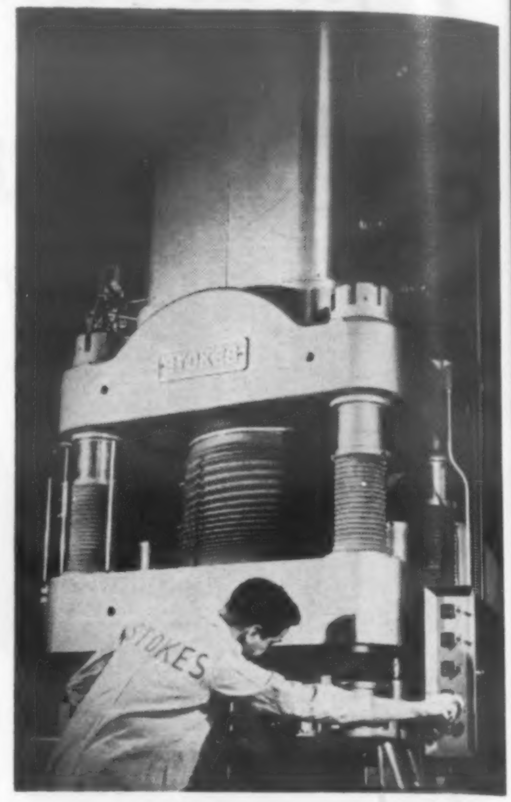
New Materials, Parts and Finishes



Jumbo Press Molds Powder Metal Parts

A new 300 ton hydraulic press is being manufactured by F. J. Stokes Machine Co., 5930 Tabor Rd., Olney P.O., Philadelphia 20, Pa. to automatically mold large powder metal parts. Parts up to 12 in. in dia and approximately 3 in. thick can be compacted and molds may have a maximum depth of fill of 8 in.

Control of the pressing cycle is automatic, and the production rate is adjustable according to the thickness of the parts. For thickest parts, the rate of operation is four strokes per min, while with thinner parts the rate increases to a maximum of ten strokes per min.

It is a double action press, each of the rams operating independently as to speed and pressure. Each ram is equipped with its own hydraulic pump and volume control. A pair of threaded stops controls the final spacing between upper and lower platens and hence between upper and lower punches.

A shuttle-type feed shoe with hardened top and bottom surfaces is said to provide accurate filling of the mold without spillage.

The control panel, located at the front corner of the press permits conversion from fully automatic to semiautomatic or manual operation at any point in the cycle.

Contents Noted

A digest of papers, articles, reports and books of current interest to those in the materials field.

This Month:

- ***Trend in Soviet Industry: Economy***
- ***Invisible Glass Fiber?***
- ***Soft Magnetic Cores***
- ***X-Rays in Industry***
- ***Plastics: The Industry, Crazing, Arc Resistance***
- ***Car Finishes Keyed to Production***

Russians Stress Economies of Engineering Materials

In Russian industry today there seems to be evidence of the same type of economic squeeze as is being felt in this country, though to be sure the causes are poles apart. But whatever the causes, the results are similar: A greater and greater stress on economy and tightness of operation in industry as a whole. This is made quite evident in a 1953 issue of *Stanki i Instr,* which contains a lead editorial and several articles stressing the need for an increased cost-consciousness and the application of basic engineering research toward the goal of reducing production costs. Digest of the editorial and two of the articles are given below.

Emphasis Laid on Material Forming and Production

In the Directive issued as a result of the 19th Communist Party session last year in the Soviet Union, ambitious plans were laid out for industrial development in all phases of industry during the five-year period ending in 1955.

In the lead editorial of the aforementioned issue of *Stanki i Instr,* it was pointed out that in order to achieve the high goals laid down by their leaders, industry must pay more and more attention to the development of high production metalworking methods, thereby gaining economies both in operations and in the engineering materials used.

An ever-widening field is predicted for stamping or pressing of metal and plastics and heavy forging since these methods lend themselves very well to cost reduction accompanied by good quality and strength in large scale production of all types of hard goods. The author reports, for example, the introduction of new and better equipment for forging and stamping work with improved carbide press tools and dies. He cites the modern hot press which permits hot stamping of components and cold finishing calibration to a dimensional accuracy of 0.05 mm and 12 g by weight. In regard to finishing, very often the only operations required are frictional surface grinding or polishing.

And, it would seem that in Russia as elsewhere, the advantages in certain cases of converting to metal stampings from machined forgings or castings are being exploited to their fullest. In some applications, this change can produce a lighter part with equal or greater strength at a much lower cost.

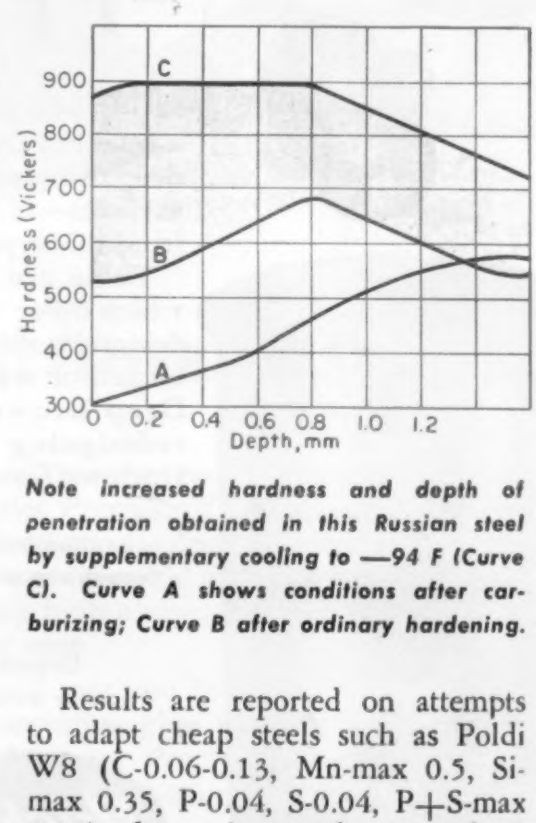
Production automation is on the upswing in Russia too, according to this report. Automatic cold forging and upsetting machines are being used for the production of screwnuts, resulting, in some cases, in a 50% reduction in waste material over the conventional metal-cutting methods.

The editorial urges increased basic research in the various institutes concerned and more training of special workers to bring about a raising of the general "cultural" and intelligence level in the factories.

Cold Treatment Allows Use of Cheap Steels for Tool Steel

In Russian factories the "innovator" (Novatori) is essentially an "idea man". He is there to think and to develop the products of his thoughts, much like the research and development engineer in this country. One such innovator is Kard Kafta, a Czechoslovakian, whose notes formed the basis for I. P. Tsyganok's article in *Stanki i Instr* on case-hardened steel tools.

In the cooling phase of normal heat treating operations on steels, in particular tool steels, case-hardened, and high alloy steels, the change from the austentic to the martensitic structure is incomplete. The lack of a complete change prejudices the hardness and certain other properties of the steel. By subsequently bringing the steel down to subnormal temperatures, change in structure can be continued, increasing hardness and stability of the metal.



Note increased hardness and depth of penetration obtained in this Russian steel by supplementary cooling to —94 F (Curve C). Curve A shows conditions after carburizing; Curve B after ordinary hardening.

Results are reported on attempts to adapt cheap steels such as Poldi W8 (C-0.06-0.13, Mn-max 0.5, Si-max 0.35, P-0.04, S-0.04, P+S-max 0.07), for various tool uses such as milling cutters. After the usual heat treatment (carburization and chilling) the tools were subjected to cold treatment for 100 min at –94 F. The hardness of the surface layer of the cutter was raised to Rockwell C 68 and the general finish was reported to be improved. In machining tests the

(Continued on next page)

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performance was said to be equal, per sharpening, to high speed tool steels, but producing better quality work. Tests were also made with the Czech steel, Poldi Autor (C-0.40-0.50, Mn-0.40-0.80, Si-max 0.40, Cr-1.4-1.7, P-max 0.035, Si-max 0.035, P+S-max 0.06), given the same treatment, and satisfactory results were reported.

Carburization of the steels was done in a bath of powdered carbon with the addition of barium carbonate, in a sealed container, then placed in a 1600 F oven for 12-14 hr. Hardening extended 1 to 1.4 mm. Further treatment after cooling consisted of preheating to 1202 F, tempering in a lead oven at about 1450 F, and water quenching followed by a half-hour soak in boiling water and subsequent sand blasting. Cold treatment in CO_2 followed within an hr in order to avoid stabilizing residual austenite.

Reports indicate that this economical application is confined to single face tools, Poldi W8 steel being considered the best for the purpose.

Anti-Friction Cast Iron As a Substitute for Bronze

Further indication of the stress on economy in Russian industry is contained in a report of a meeting of the Russian Committee on Metal Economy held in Moscow in July of 1953. The meeting was organized by the All Union Scientific Institute of Technical Societies, and resolutions were made to revise Russian standards (GOST) in accordance with recently developed and tested classifications of cast irons.

The anti-friction cast irons may be classified into three groups according to the form of the graphite; i.e., flaky or lamellar; heat-treated carbon; or spherical.

The flaky or lamellar graphite group includes the Russian Ts1 and Ts2 standard alloys which are intended for use in small units with peripheral speeds not exceeding 2 m per sec with loads up to 20 kg per sq cm. In addition, they will not withstand impact loads or shock.

The Institute for Agricultural Machine Construction, working in conjunction with the Stalin works of the Rostcel'mash (possibly standing for Rostov Agricultural Machine Trust) has developed and tested anti-friction pearlitic or pearlito-ferritic wrought irons, with graphite in the

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continued

form of heat-treated carbon. These irons, either centrifugally cast or chill cast, are intended for use under impact conditions and are wholly without non-ferrous metal constituents. They are reported to have a wide range of use in metal cutting machines, forging and stamping machines, and in tractors.

Results are given for tests on two of these normalized pearlito-ferritic wrought irons having different analyses. One was 35-80% pearlite with a Brinell hardness of 167-197, while the other was 80-100% pearlite with a Brinell hardness of 197-217. The average strength was found to be 58 kg per sq mm, specimen elongation was 4 to 9%, and the loads on the testing machines were as high as 400 kg per sq cm. The investigators concluded that phase change and control, e.g. pearlite content, were of great practical importance.

Iron with spherical graphite and a magnesium finish was reported to have greater strength or stability than the wrought iron, despite the higher carbon content and plasticity of the latter. It was generally concluded that these anti-friction magnesium coated irons have great possibilities of application in replacing bronze bearings, and the conferees at the meeting agreed that as well as revising the Russian standards, the irons should be used for reconditioning existing machines as well as in the manufacture of new ones.

Why Not Invisible Reinforcing in Plastics?

G. Slayter, one of the pioneers in the field of glass fiber reinforced plastics, in 1943 envisioned a perfect index match of the glass fibers with the bonding resin so that the resulting form would be perfectly clear and transparent, and the fibers, for all intents and purposes, would be invisible.

A paper presented by Edwin F. Bushman before the Society of The Plastics Industry, Inc., this year pointed up the effect the reinforcing fiber may have on the saleability of the resulting product. In so doing, he pointed out the problems which hinder the commercial accomplishment of Slayter's ideal.

In the first place, it is necessary to

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continued

match perfectly the index of refraction of the glass fibers with that of the cured resin. Also, since glass filaments abrade easily, do not bond well to polyester type resins, and have a low wet strength, a sizing agent or binder must be applied to the glass fiber. This, in turn, must have a matching index, must not reduce light transmission of the laminate, and should be colorless.

During impregnation, the resin must completely replace all minute air pockets, vapor, etc., from within the glass filament bundles. All glass fiber surfaces must also be completely wetted by the resin, and during curing, this perfect contact of resin with all glass surfaces must be maintained. In effect, this implies absolutely no shrinkage of resin in relation to the fiber during cure. Any minute separation of resin from glass filament during cure would open up tiny glass, vapor, or resin voids which would scatter the light, producing a haze effect.

In order to produce a flat surface plane on the sheet, a perfect match of thermal coefficient of expansion of resin to glass is required. And finally, the author points out that though Slayter was working with fibers of less than 10 microns in dia, commercial roving filaments today range in dia from 0.0002 to 0.00075 in.

Ferrites Plug the Gap in Soft Magnetic Cores

Magnetically soft materials include pure iron, iron-silicon alloys, iron-nickel alloys, iron-cobalt alloys, and ferromagnetic oxides or ferrites.

In the Dec. 3 issue of *Stahl und Eisen* last year, H. Fahlenbrach and W. Heister collaborated in a round-up type of article stating the development and present state of magnetically soft materials, and ferrites in particular.

They point out that the ferrites close a gap that previously existed between the most satisfactory frequency ranges for cores built up of very thin sheet, and that of powdered cores. The high specific electrical resistance of ferrites (10^6 ohms-cm)

Contents Noted continued

greatly decreases eddy-current losses. However, it is pointed out that the magnetic saturation of these materials lies between two and 4000 gaus, so they are not satisfactory for the high-tension field where very high induction is demanded.

The permeability varies inversely with the limiting frequency, above which a marked decrease in permeability occurs. The selection of a ferrite for very high frequencies, therefore, necessarily results in a decrease of the initial permeability.

Magnetically soft ferrites have a wide range of application including telephones, television and radio. They have already found wide use as filter cores, where extraordinarily high values can be obtained by the introduction of an artificial air gap, and as cores in television scanning transformers. The authors believe that ferrites will in many cases replace the present materials in the low-frequency field also because of simplicity of production.

What's New in X-Ray for Industry?

In the years since the last war, improvements in x-ray equipment and techniques have rapidly expanded the use of this process in industry, according to Dr. John E. Jacobs, of G-E's X-Ray Development Laboratory.

In a speech before the American Society of Mechanical Engineers last January, Dr. Jacobs went on to say that newly developed methods and materials have made feasible and practical non-destructive testing for industries which only a few years ago regarded x-radiation as a tool of the practising physician only.

Causes of Expansion

In recent developments solid state physics has been utilized in two ways. First, due to increased knowledge as to the mechanism of phosphorescence, materials have been developed which exhibit high light output and fast response time when subjected to radiation. Blocks of these materials, in effect, absorb invisible x-rays, and transmit them as visible light, indicating varying intensities. These materials should greatly extend the use-

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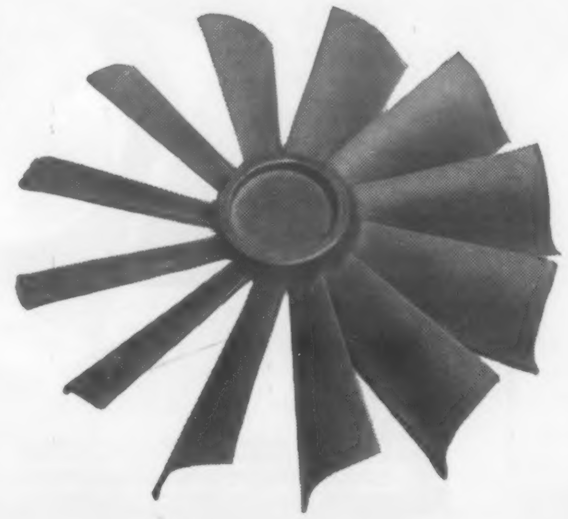
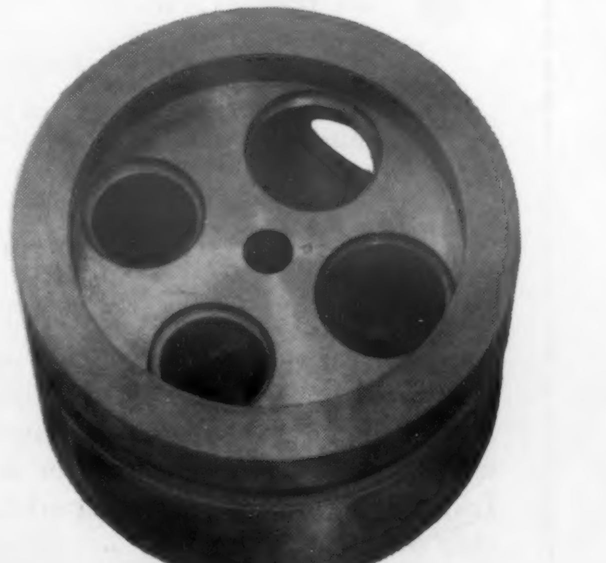


PRODUCED FOR 74 PER CENT LESS

Originally this turbine wheel was machined from a 20-lb. forging to a final weight of a little over 1 lb. Now the part is produced by investment casting and only 2 oz. of metal is removed. Investment casting has brought about a 74 per cent reduction in production costs by saving strategic metal and machine time.

COST CUT 60 PER CENT

This investment-cast motor mount was made in a high-strength alloy at 60 per cent less than the cost of a forging. The mount bears the entire weight and torque of a 100-lb., 15-horsepower aircraft starter motor. The investment-cast parts require only four simple finishing operations.



ASSEMBLY COSTS REDUCED

Investment casting made it possible to produce this cylinder head in one piece, eliminating extra assembly costs. Machining was reduced to a minimum. The design of the part is special to investment casting. The castings weigh about 25 lb. and are 7 in. in diameter.

HAYNES *investment castings can solve some of your own production problems. For more information, contact the nearest Haynes Stellite Company office listed below.*

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fulness of x-ray diffraction instruments.

The other phase of solid state physics which is aiding industrial x-ray use is photoconduction. This refers to electronic conduction in solid materials that is precisely controllable by controlling the amount of radiation applied to the material. Typical of the rare materials which possess this property are germanium, selenium and cadmium sulfide. The use of these materials has been instrumental in substituting high speed, automatic processes for film radiography.

A third basic science Dr. Jacobs describes is that of Electron Optics, which deals with the intensification of the x-ray image for viewing.

New Applications

An example of the results of recent developments in the field of x-ray technology is a process termed xeroradiography. Roughly, the process operates as follows: a thin layer of red selenium is deposited on a metal plate and is charged so that a potential difference exists between the metal plate and the front surface of the selenium. The plate is then exposed to x-radiation, in essentially the same manner as conventional x-ray film. The impinging x-radiation discharges portions of the plate by photoconduction. The latent charge pattern is then developed by subjecting the plate to a cloud of fine particles which adhere only to the charged surface of the plate and thus form a pattern.

The advantages of this process lie in the fact that 1) it eliminates cut film, wet chemicals, and dark room processing; 2) the xerographic plates may be cleaned and reused; and 3) it permits rapid inspection, since the plate may be viewed immediately following exposure and dry powder developing.

The Future?

Dr. Jacobs points up the fact that in the future, commercial development of all types of equipment, e.g. the transitor, promises to increase to an even greater extent, the reliability and versatility of the x-ray process of quality and process control. Also, that with the industrial processes turning more and more towards automation, quality control and testing methods must keep step.

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Car Finishes: Enamel & Lacquer

Automotive finishing has become a highly mechanized process. Developments in the finishing materials used therefore have been to a great extent dictated by the requirements of the production line. In 1923 painting a car took 432 hr of drying time while current schedules in some instances call for as little as 45 min drying time from bare metal to finished surface.

A group of papers presented at the National Passenger Car Body and Materials Meeting of the Society of Automotive Engineers in March of this year, point up the fact that coupled with this drastic reduction of processing time there has been a vast improvement in the quality of the finishes.

Car body finishes are of two general types: lacquers which dry by a simple evaporation of the solvents used to apply them, and enamels which dry by polymerization of the film-forming ingredients.

Enamels Catch up

Todays enamels are dried in three ways: 1) Air drying at room temperature, used for repair in the field; 2) low temperature baking at 180 to 200 F, used for repair in the plant; and 3) baking at about 250 F, used as standard body enamels in the production line.

Probably one of the most important areas of progress has been the development of new and better dry colors. Phthalocyanine blues and green, indanthrene blue and some metallized azo dyes have opened spectrums of color never before available in enamels for exterior exposure. Rutile titanium oxide, modified with other metal oxides and greatly improved maroon pigments have widened the field by allowing extremely light tints in body enamels. Better BON maroons, thio indigo reds, cadmium selenides, arylide maroons and colloidal hydrated ferric oxide have enabled the enamels to rival the lacquers that dominated the field for some years.

In addition to these improvements in the color range of enamels, there have been advantages gained in 1) increased gloss, 2) lower baking time and temperature, 3) higher solids

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content—15 to 20% at spraying consistency, 4) diminished film shrinkage, 5) less chalking and bronzing, 6) better stability, and 7) greater resistance to water, soap, gas, etc., to mention a few.

Lacquers Keep Pace

The advantages which lacquers have held over enamels in plant application have been primarily in the shorter times and lower temperatures needed for drying. Though present enamels can be dried in approximately the same amount of time and only about 60 to 70 F higher temperatures than the lacquers, the latter can provide more brilliant and pleasing colors and the finish is more durable. The application of lacquers has become a science, in that viscosity, air pressure and time and temperature must be closely regulated.

Though many consumers are unaware of it, the lacquer finish has a rubbed and polished appearance, while the baked enamel shines. The polishing operation on the lacquer tends to remove the slightly dimpled or orange peel pattern resulting from the spray application of almost any finish.

Though baked enamels can now be dried in the plant as speedily as lacquers, in the field repairing of either enamel or lacquer finishes, the faster air-drying qualities of the lacquers give them the advantage of speedy repairs with a minimum of trouble. Rapid drying is also an advantage in painting in two colors since after the application of one color, that area can be masked almost immediately and the other color applied next to it.

What Next?

Automotive finishes are continually being improved. Both mechanical properties and color are constantly being studied. Gloss retention, while good in the deep browns and deep greens, is under study for improvement in other colors.

Silicone enamels, though high in gloss and chalk resistance require bake temperatures too high for practical automotive use. They also have an unsatisfactory balance between hardness and flexibility. Combinations with alkyds that will convert at temperatures from room temperature to 300 F have been produced, but they have poor blister resistance. Polyacrylate and vinyl chloride resins


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are also under study. Epons, cross-linked with urea-formaldehydes show interesting properties, but have short pot life.

With the recent introduction of plastic car bodies, the need for enamels curing at low enough temperatures not to endanger the plastic material is being met by new curing agents, possibly some of the diisocyanates. All these materials are being explored and improvements are made daily. Work is progressing.

(This is a correlated abstract of *Lacquer as a Finish on Automobiles*, by Ralph J. Wirshing, Research Lab. Div., General Motors Corp.; *Automobile Enamels, by* A. J. Lapointe, Lincoln-Mercury Div., Ford Motor Co.; *Evaluation of Automotive Finishes*, by R. I. Peters and H. W. Redshaw, Ditzler Color Div., Pittsburgh Plate Glass Co.; and *Trends in New Automotive Finishes*, by Roy B. Davis, E. I. du Pont de Nemours & Co.)

Crazing of Plastics; Cause and Effect

The relative importance of crazing of plastics to the engineer depends on the requirements of the end-product. In the structural part, the importance lies in the weakening of the material; in the transparent plastic used for optical purposes, it lies in the variations of the index of refraction caused by the crazing.

In a paper presented at an annual meeting of the American Society of Mechanical Engineers and reprinted in the SPE Journal in November last year, J. A. Sauer and C. C. Hsiao review some of the factors affecting crazing, its mechanics, and what it means to the design of a part.

Stress, Time and Material

Crazing cracks generally start on the surface and extend in a direction perpendicular to the direction of maximum tensile stress. It also seems to begin more easily when a local discontinuity such as a scratch, introduces stress concentrations which are higher than the average stress in the piece. Since surface irregularities are unavoidable, crazing usually occurs first on the outside surfaces of the plastic. And, as would be expected, crazing generally increases with increase of applied tensile stress and length of time the stress is applied.

(Continued on next page)

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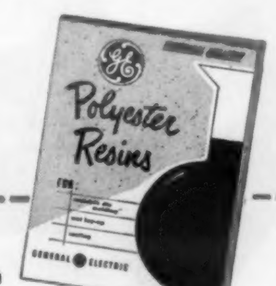

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The authors also point out that crazing does not depend wholly on stress and time, but also on the material itself. For example, for comparable stress and time as well as surface conditions, crazing cracks in polymethyl methacrylate specimens are usually larger and less dense than those in polystyrene specimens, but do not extend as far from the surface.

Interesting results were reported on a strength test on polystyrene specimens which were completely crazed throughout their cross-section. These fully crazed pieces were found to have approximately the same ductility and somewhat more than ½ the tensile strength of the uncrazed material. It would seem from this that even fully crazed parts can carry a considerable load.

In the growth of crazing cracks, it was found that the depth of the cracks can be expressed as a linear function of both stress magnitude and time. And the authors develop equations which imply that the rate of propogation of crazing goes to zero for some limiting stress value, which seems to be in agreement with experimental results.

Affects Design

In considering crazing of plastics from the standpoint of the design of a part, several factors are pointed out. Since crazing, once started, will continue without an increase in applied stress, it is wise to consider very carefully all the strength requirements in order to prevent its start in the first place. In other words working stress magnitudes should be established not merely on the basis of the static ultimate strength of the material, but on strength values at which crazing is found to occur.

Surface coatings are said to be helpful in preventing crazing. Also, in applications where tensile stresses will be encountered in varying directions, full annealing of the plastic sheet is desirable since the material can be made more nearly isotropic. On the other hand, if the part is to be used only under uniaxial tension, the higher working stresses can be obtained by use of highly oriented material. This is due to the fact that in the orientated state all the molecular chains tend to align in the direction of orientation and crazing which is believed to be the result of lateral separation of adjacent chains cannot occur in this condition.

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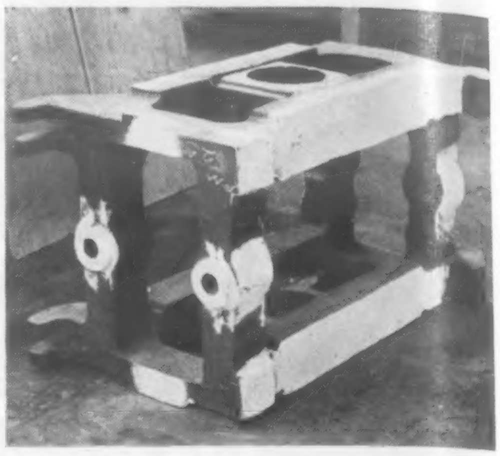

Frame casting (2000 lb), made with 1/4 in./ft shrinkage rule had to be recast due to complete lack of shrinkage.

No Strict Rule For Shrinkage in Castings

Shrinkage in medium and large steel castings in one foundry often differs from that in another. Therefore, the foundry should be permitted to make the pattern with allowances for proper shrinkage or else be given the right to specify the shrinkage and finish allowances, according to Hubert Chappie, Foundry Supt., The National Supply Co.

In a paper delivered before a group of the Steel Founders' Society of America, Mr. Chappie went on to explain why there are no hard and fast rules for specifying shrinkage in larger steel castings, as there may be for the average small one. Hindered contraction, caused mainly by design and the materials and methods used in molding and coring, was named by the author as the major cause of variations in contraction.

Sand ingredients are the principal causes of hindered contraction, the amount of silica flour affecting the mold or core restrictions considerably. If the hot strength of the sand exceeds 23 psi at 2500 F, the possibility of hot tearing of the casting increases. Since green sand does not have the strength of dry sand to resist shrinkage, molds in green sand shrink much more than those in dry sand.

The author goes on to point out that as well as the influence of the sand itself, the individual foundry techniques affect shrinkage considerably. Steel gaggers and bars prevent the mold from contracting, thereby minimizing linear shrinkage. Ramming affects linear shrinkage in that the harder the sand is rammed, the

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continued

less the shrinkage. Several heads on one casting affect the shrinkage, and this can be counteracted in several ways, by means of relieving blocks, loose dirt or chains. All these factors, varying from foundry to foundry seem to point up the need for individual foundry specifications for pattern making insofar as shrinkage and amount of finish are concerned.

The Plastics Industry—What to Expect

Though there will certainly be new plastics developed in the future, we cannot expect such a flood of new materials as we have experienced since 1930, according to A. Renfrew of the Imperial Chemical Industries of England. In a paper presented at the 10th Annual Technical Conference of the Society of Plastics Engineers, Inc. this year, Mr. Renfrew went on to say that any new plastics developed will probably be quite expensive.

With the remarkable developments of the last 20 years in the plastic field behind us, we can now look forward to growth in two general directions: 1) quality, uniformity and standardization in plastic materials, and 2) a wider field of application for the improved materials.

More Emphasis on Quality

One of the big troubles in the plastics industry, Mr. Renfrew points out, has been the use of good materials by some fabricators to produce poor products in order to gain a quick financial return. The newness of the plastics industry perhaps is partially to blame for this in that there has been no time for the growth of a tradition of workmanship or for the development of knowledgeable buyers. The need now is for the development of standard specifications and an increased understanding of the structure of plastics and how to control it.

In support of his belief, Mr. Renfrew points out that such terms as "crystallization" and "texture" are becoming more and more meaningful to the businessman in terms of the quality of his plastic product. And

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deeper knowledge of such phenomena as texture, which arises from the crystalline amorphous ratio, will both broaden the scope of the materials and improve the resultant products.

New Uses—Second Path of Progress

The most obvious line of development for the plastics industry is in finding new applications. The uses of the materials to date range widely through auto bodies, plastic pipe, synthetic fibers, etc., and in many industries their use has become so widespread that the industries could scarcely exist without them.

Mr. Renfrew points out also that usually the original application for a new plastic is less important than those which arise after a few years. The new uses coupled with improvements in fabricating techniques, the author says, promise to be the major lines of development in the field.

Nine Plastics Tested For Arc Resistance

Increasing concentration of electric power at higher voltages in airplanes of today and tomorrow has created the need to review the insulating materials now used in the light of these increasingly severe conditions.

In a paper presented before the Tenth Annual Technical Conference of the Society of Plastics Engineers, Inc. this year, T. J. Martin and Raymond L. Hauter pointed out the results of tests conducted by Boeing Airplane Co. to evaluate nine types of plastics used as insulation. The power used in the tests was much higher than is commonly encountered in today's airplanes, but it lies in a range that will no doubt be used in the future.

Power for the tests was supplied by 3-phase 400 cps 208/120 v aircraft alternators. The fault currents applied to the insulating materials were about 800 amps for single-alternator tests and about 3200 amps for four-alternator tests. Arcs were applied across the face of the material tested, simulating emergency arcing-in-service conditions. The materials discussed are in ascending order of arc resistance.

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Phenolic Materials

This was the material whose poor behavior caused the investigation to be made. It took only one arc with power from one alternator to cause complete destruction of the material, accompanied by violent flames and much smoke.

Modified Phenolic

This material, had an improved arc resistance of 180 sec according to Standard ASTM test procedure. This is comparable to the melamines.

Three tests were made—using one 60-kva alternator. As the arc was drawn out, the voltage across the arc increased and the current decreased. The arc was cleared manually after 1.79 sec. By this time the conductivity of the plastic surface was so high due to carbonization that the arc restruck immediately after the contactor was re-closed, and continued at all times that the power was applied. Violent flaming accompanied the arcs.

Obviously this material, used in limiter blocks or circuit-breaker cases, would give no protection to the electrical system, and therefore should not be used in aircraft insulation where there is any possibility of exposure to arcs, or where tracking caused by surface leakage is a possibility.

Alkyd Resins

Mineral filled alkyd resins with an ASTM arc resistance of 180 sec, generally withstood one arc at 200 v, though many samples then failed when the voltage was raised to 350 v. The second arc destroyed the samples surviving the first. It appeared that the mineral-filled alkyd is better than the phenolics but still leaves much to be desired.

The samples of glass-filled alkyd resins all failed completely on the first arc. It is somewhat inferior to the mineral-filled material in arc resistance.

Epoxy Resin

Tests were run with one alternator on a laminated glass cloth bonded with an epoxy resin. The material passed the first test. The resin was burned away leaving the glass fibers exposed, but the arc was interrupted and the insulation apparently remained good. The second arc completely destroyed the material.

Melamines

Three samples of wood-flour filled melamines survived two arcs each and failed on the third. A fourth

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sample failed on the first arc.

Tests on mineral-filled melamine were run with fuse clips mounted on the inside of a relay case molded of the material. After the fourth test, 460 v, 400 cycle a.c. was applied. Small pinpoint arcs appeared in the first few seconds. The voltage was applied for 9 hr after the 6th test. Intermittent pinpoint arcs appeared but there was no breakdown.

Although this material will carbonize after repeated power arcs it is considered satisfactory for application as electrical insulation except in such limited applications as arcing chambers, etc., where it would be repeatedly exposed to arcs.

For applications where carbonization of the material can result only from failure of equipment, this material should give adequate performance.

Teflon

The material survived seven arcs with no sign of carbon tracking. Starting with the first arc there were signs of decomposition near the terminals, forming a non-conductive black substance that looked like pitch. However, with the application of 350 v after each arc, there were no signs of carbon tracking.

Within the limits of its molding problems and its mechanical characteristics, Teflon would appear to have distinct advantages as insulating material under arcing conditions. Nevertheless, limitations exist in the toxic and corrosive gases emitted during decomposition.

Glass-Bonded Mica

Glass-bonded mica will not form a carbon track. Due to certain unknown properties of the material the voltage had to be raised to 330 to 350 v in order to get an arc started.

The material was subjected to eight tests at this voltage. After each test, a little of the material had disappeared. However, after eight tests, the resistance of the material had apparently not been substantially reduced.

Having survived the single-alternator tests, the material was then subjected to arcs with four 60-kva alternators in which the fault currents were about 3200 amp. After four such arcs, the sample looked very much like the sample subjected to one alternator after six tests.

(Continued on next page)

How many SPARKS in a Spark Plug?

Surprising, the confidence that people have in spark plugs. No one stops to question how many "sparks" they're good for, because long-life performance has come to be taken for granted. Yet, when you get right down to it, you'll find good reasons for this complete consumer confidence. And, from a "sparking" point of view, perhaps the most important is the almost universal use of special Hoskins alloys for the vital electrode wires.

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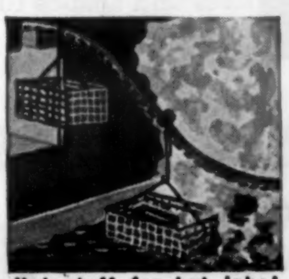

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Books

MATERIALS AND PROCESSES. *James F. Young, John Wiley & Sons, Inc., New York, N.Y., 1954. Cloth, 6 by 9 in. 1074 pp. Price $8.50.*

This volume is a revision of a work published previously in 1944. It presents a broad study of engineering materials and manufacturing processes from the viewpoint of the engineer. It has been organized to provide for textbook and reference use by students and practicing engineers, particularly those concerned with product development, design, production, processing and applications.

The book is divided into two parts, dealing respectively with materials and processes. Part one contains 14 chapters, five of which are concerned with the nature of metals and alloys and a general discussion of properties. The remaining chapters take up specific materials. In this group, chapters are devoted to iron and steel, nonferrous metals and alloys, nonmetallic materials, plastics, rubber and ceramics.

Ten chapters discussing processes are included in Part two. Subjects include casting, powder metallurgy, heat treatment, hot and cold working processes, welding, machining, cleaning and finishing, inspection and quality control.

Chapters contain review questions and references to the sources of additional information. This book is one of a series written in the interest of the General Electric Educational Programs, and is intended particularly for classroom use. However, the engineer will find much useful information in it.

THE ELEVATED-TEMPERATURE PROPERTIES OF CHROMIUM-MOLYBDENUM STEELS. *Published by American Society for Testing Materials, Philadelphia 3, Penna., 1953. Paper, 8 by 11 in., 212 pp. Price $4.75.* This is the second in a current series of reports prepared under the auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals. This report is a graphical summary of the elevated-temperature strength data for the chromium-molybdenum steels. It includes summary curves for tensile

strength; 0.2 percent offset yield strength; percent elongation and reduction of area; stresses for rupture in 100, 1000, and 100,000 hr; and stresses for the creep rates of 0.0001 and 0.00001 percent per hr (1 percent in 10,000 and 100,000 hr); and Larson-Miller master curves.

RECOMMENDED PRACTICES FOR REPAIR WELDING OF CAST IRON PIPE, VALVES AND FITTINGS. *Published by The American Welding Society, New York 18, N.Y., 1954. Paper, 6 by 9 in. 12 pp. Price 50 cents.* These recommended practices just published by the Society give practical details of the repair methods which should be used. Materials covered include gray iron, white cast iron, chilled cast iron, malleable iron, alloy cast iron and nodular cast iron. The welding process for which procedures are given include arc welding with nickel electrodes, mild steel electrodes, cast iron electrodes and copper-base electrodes, oxyacetylene welding and braze welding, and carbon arc welding.

SYMPOSIUM ON FRETTING CORROSION. *Published by American Society for Testing Materials, Philadelphia 3, Penna., 1953. Paper, 6 by 9 in. 88 pp. Price $2.00.* The papers included here were presented at the Symposium on Fretting Corrosion held at the ASTM 55th Annual meeting. Titles and authors are: *Introduction,* T. E. De Villiers; *The Current Status of Fretting Corrosion,* W. E. Campbell; *Fretting Corrosion Tendencies of Several Combinations of Materials,* J. R. McDowell; *Influence of Fretting Corrosion on the Fatigue Strength of Fitted Members,* Oscar J. Horger; *Effect of Lubricants in Minimizing Fretting Corrosion,* E. W. Herbek, Jr. and R. F. Strohecker; *Test Equipment for Evaluating Fretting Corrosion,* H. H. Uhlig, W. E. Tierney and A. McClellan.

RECOMMENDED PRACTICE FOR POSTWELD HEAT TREATMENT OF AUSTENITIC WELDMENTS. *Published by American Welding Society, New York 18, N.Y., 1953. Paper, Price 50 cents.* Summarized here are the considerations necessary to determine whether, for a given application, stress relief should be used, and if so, at what time and temperature. The recommendations represent the practices deemed most acceptable by a group of authorities on the subject,

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based on studies and actual industrial application.

40TH ANNUAL PROCEEDINGS AMERICAN ELECTROPLATERS' SOCIETY 1953. *American Electroplaters' Society, Newark 2, N.J., 1953. Cloth, 8 by 11 in. 154 pp.* Included here are the papers presented at the Society's 40th annual convention plus the business conducted.

Reports

Aluminum and Stainless Turbine Wheels Heat-Transfer and Operating Characteristics of Aluminum Forced-Convection and Stainless-Steel Natural-Convection Water-Cooled Single-Stage Turbines. *John C. Freche and A. J. Diaguila, June 30, 1950. NACA RM E50DO3a, 48 pp, diagrams, photographs, 2 tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D. C.* Two water-cooled turbines were operated, one with blades and disk of aluminum alloy cooled by forced convection and the other with blades and disk of stainless steel cooled by natural convection. Heat-transfer data, coolant pumping power, and operational data, such as gas temperatures, coolant-flow rates, and blade temperatures, are included. The heat-transfer results for both turbines agreed with those for static-cascade and stationary-tube investigations.

Thermal Conductivity Thermal Conductivity of Metals and Alloys up to 1100 F. *Jerry E. Evans, Jr., March 2, 1951. NACA RM E50LO7, 15 pp, table. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* Metals tested include steels, high-temperature alloys, molybdenum disilicide, aluminum alloys, brass, and silver. The method used in obtaining the results was a comparison method wherein the test sample was compared with high-purity lead.

Porous Turbine Blades Experimental Investigation of Coolant-Flow Characteristics of a Sintered Porous Turbine Blade. *Edward R. Bartoo, Louis J. Schafer, Jr. and Hadley T.*

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Richards, Feb. 1952. NACA RM E51K02, 28 pp, diagrams, photographs. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C. Local cooling-air flow rates through the walls of a sintered porous metal turbine blade were measured at room temperature for a range of pressure drops. This procedure was used to correlate air-flow rates through two porous disks for temperatures up to 600 F. Data indicate that room temperature flow data can be used for heat-transfer work at elevated temperatures with reasonable accuracy.

Molybdenum Disilicide Oxidation-Resistance Mechanism and Other Properties of Molybdenum Disilicide. *W. A. Maxwell, March 1952. NACA RM E52A04, 17 pp, diagrams, photographs, tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* The outstanding oxidation resistance of the material at 2400 F and above was found to depend on the formation of a protective siliceous coating in which alpha-cristobalite has been identified. In powdered form, molybdenum disilicide burns at low temperatures. The room temperature modulus of elasticity has been determined and electric resistivity data are given at 2000 F.

Properties of Certain Intermetallics as Related to Elevated-Temperature Applications. 1-Molybdenum Disilicide. *W. A. Maxwell, Oct. 6, 1949. NACA RM E9G01, 27 pp, diagrams, 4 tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* The modulus-of-rupture strength and oxidation resistance at 2000 and 2400 F was studied as well as the general properties. Sintered molybdenum disilicide was found to have high comparative strength at 2400 F. The material deformed plastically at temperatures well below the melting point despite complete brittle behavior at room temperature.

Titanium Carbide Base Ceramals Investigation of Titanium Carbide Base Ceramals Containing Either Nickel or Cobalt for Use as Gas-Turbine Blades. *C. A. Hoffman and A. L. Cooper, Aug. 1952. NACA RM E52H05, 33 pp, photographs,*

For more information, Circle No. 443 ➤

diagrams, 5 tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C. The effectiveness of a number of methods of preventing ceramal-blade-root failure was studied. The results indicate that both the 66.5% TiC plus 18.5% Co plus 15% (CbTaTi) C and 66.5% Tic plus 18.5% Ni and 15% (CbTaTi)C ceramals should be considered further for gas-turbine-blade use. The oxidation resistance of both the materials appears to be adequate for practical blade application. Further work on blade root design and mounting methods is required to eliminate root failure which is the factor limiting the usefulness of ceramels as gas turbine blade material.

Temperature Effect on a Ceramic Thermal Shock Resistance and High-Temperature Strength of a Molybdenum Disilicide—Aluminum Oxide Ceramic. *W. A. Maxwell and R. W. Smith, Oct. 1953. NACA RM E53F26, 8 pp, photographs, 4 tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* Thermal-shock resistance, high temperature modulus-of-rupture strengths were determined for a ceramic having nominal composition 75% molybdenum disilicide, 25% aluminum oxide. The material was found to have improved thermal-shock resistance as compared with pure molybdenum disilicide and to have moderate high-temperature strength.

Metals in Skin-Stringer Panels Data on the Compressive Strength of Skin-Stringer Panels of Various Materials. *Norris F. Dow, William A. Hickman and B. Walter Rosen, Jan. 1954. NACA TN 3064, 49 pp, diagrams, photograph, 7 tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* Flat compression panels of stainless steel, mild steel, titanium, copper, four aluminum alloys and a magnesium alloy were tested.

Fatigue Testing Aluminum Fatigue Tests at Stresses Producing Failure in 2 to 10,000 Cycles. 24S-T3 and 75S-T6 Aluminum-Alloy Sheet Specimens with a Theoretical Stress-Concentration Factor of 4.0 Subjected to Completely Reversed Axial Load. *Herbert F. Hardrath and Walter Illg, Jan. 1954. NACA TN 3132,*

Contents Noted | Reports continued

14 pp, *diagrams, photograph,* 2 *tables. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* Notched specimens were subjected to completely reversed axial loads. The fatigue strengths were equivalent for specimens made of each of the two materials and tested at stresses below 25 ksi; above that stress the 75S-T6 specimens had the greater fatigue strength. Compared on the basis of per cent of ultimate tensile strength, the 24S-T3 specimens were stronger at all stress levels.

Declassified Materials List A Restricted List of Aircraft Materials Research Projects. *Sponsored by Government Agencies, May 4, 1948. NACA RM 8C29, 95 pp. Available from the National Advisory Committee for Aeronautics, 1724 F St., N.W., Wash. 25, D.C.* Report contains a list of Government sponsored research projects on related aircraft products in the calendar year 1947.

Titanium Brazing Titanium to Titanium and to Mild and Stainless Steels. *Wright Air Development Center. PB 111244, 38 pp, photographs, diagrams. Available from Office of Technical Services, U.S. Dept. of Commerce, Wash. 25, D.C. $1.00.* Successful brazing of these materials is reported by Battelle Memorial Institute. Good joints were obtained by both controlled atmosphere furnace and oxyacetylene torch, using commercial fluxes and alloys. Good preliminary results are also reported for resistance, induction, and inert-gas-shielded carbon arc.

Development of Titanium-Base Alloys. *PB 112227, 158 pp. Available from Library of Congress, Publication Board Projects, Wash. 25, D.C. Microfilm $6.00, Photostat $20.00.* Report describes how solution treating, machining and then age-hardening may give titanium outstanding tensile properties that will be stable at operating temperatures as high as 600 F.

The grinding of Titanium Alloys. *PB 112049, 76 pp. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $3.50, Photostat $10.00.* Practical recommendations are given for the grinding of titanium alloys. Report also summarizes grinding characteristics for representative titanium alloys.

For more information, Circle No. 313 ➤

news of ENGINEERS COMPANIES SOCIETIES

News of Engineers

Sidney Rolle having retired from The Scomet Co. and The American Metal Co., Ltd., has opened an office as consulting metallurgical engineer at Room 2809, Graybar Bldg., New York 17, N.Y.

William Adam, Jr. has been elected president of Ajax Electric Co., succeeding **Dr. G. H. Clamer** who is retiring from that office. **John E. Haig** and **Leon B. Rosseau** were elected vice presidents of the company.

Franklin H. Bivins has been named general manager of Vitro Rare Metals Co., a division of Vitro Corp. of America.

William B. Hall has been named general manager of Vitro Uranium Co., a division of Vitro Corp. of America.

Joseph Boyce has been named general manager of Vitro Manufacturing Co., a division of Vitro Corp. of America.

Harry B. McClure has been appointed president of Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp.

Robert S. Ames, manager of canopy and laminates operations at Goodyear Aircraft Corp., has been reappointed to the Subcommittee on Aircraft Structural Materials organized by the National Advisory Committee for Aeronautics.

Louis Calzi has been appointed to the development metallurgical staff of Superior Tube Co.

Charles J. Demrick has been elected vice president in charge of manufacturing, Plymouth Motor Corp. Mr. Demrick was previously general manufacturing manager.

Dr. Robert D. Huntoon has been named associate director for physics, National Bureau of Standards.

John Lackman has been named executive technical director, Chester Cable Corp.

Wallace F. Armstrong has been promoted from manager of the Houston plant to assistant general manager of manufacturing, Ethyl Corp.

(Continued on next page)

MODERN METALS *Need Modern Chemicals*

Investigate B&A *Fluorides and Fluoborates*

The Light Metal Industry

1. **Alkali Fluoborates (Ammonium, Potassium, Sodium)**
   For use as purifying and melting fluxes, oxidation inhibitors, grain refining agents, and for heat-treating.
2. **Potassium Chromium Fluoride**
   To introduce small quantities of chromium in aluminum alloys.
3. **Potassium Titanium Fluoride**
   For grain refining and improved tensile strength.

The Electroplating Industry

4. **Metal Fluoborates (Lead, Tin, Iron, Copper, Nickel, Cadmium, Indium)**
   Electrolytes for plating baths; help increase plating output, lower operating costs, conserve critical plating metals.
5. **Sodium Acid Fluorides**
   For use in acid plating baths.
6. **Magnesium Fluoride**
   For use with chromic acid for surface treatment of magnesium.

Gray Iron Castings

7. **Potassium Fluoborate**
   To increase fluidity, machinability and tensile and transverse strengths.

Steel

8. **Sodium Fluoride**—For rimming.

Powdered Metallurgy

9. **Ammonium Fluoborate**
   To impart desired porosity.

Other B&A Fine Chemicals for the Metal Industry:

10. Acid Fluoboric
11. Acid Hydrofluoric, Reagent
12. Aluminum Chloride, Solution
13. Aluminum Fluoride, Crystal
14. Ammonium Acetate
15. Ammonium Oxalate
16. Ammonium Sulfate, Purified and Reagent
17. Ammonium Thiosulfate
18. Boron Trifluoride, Gas and Various Complexes
19. Chromium Fluoride
20. Cuprous Chloride
21. Ferrous Ammonium Sulfate
22. Lead Nitrate
23. Potassium Acetate
24. Potassium Bifluoride
25. Potassium Borate, Tetra
26. Potassium Nitrite
27. Stannous Chloride

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news of | ENGINEERS

Ralph E. Cross, director and executive vice president, Cross Co., has been appointed as director of the Metalworking Equipment Div., Business and Defense Services Administration, U.S. Dept of Commerce.

H. L. Wagener has been named special consultant to the technical research group, KSM Products, Inc.

Herbert E. Brumder, general manager, was elected president and treasurer of Downingtown Iron Works, Inc., a division of Pressed Steel Tank Co.

Frank R. Ward has joined the Atomic Power Div., Westinghouse Electric Corp., as a project coordinator in the Reactor and Materials Dept. Mr. Ward was formerly on the staff of the Division of Reactor Development, Atomic Energy Commission.

William C. Rowland, formerly head of the Manufacturing and Repair Div., Wetinghouse Electric Corp., has been assigned responsibility for the Steam Div. which operates the firm's largest plants at South Philadelphia. Succeeding Mr. Rowland is **Chris Bartlett,** formerly assistant manager of the Transformer Div. **Ray H. Timmons** has been named works manager of the Steam Div.

George H. McBride, formerly assistant manager of the Westinghouse Switchgear Div., has been appointed manager of the company's Micarta Div.

E. Mortensen has been elected president of Wesson Tool Co.

Richard T. Ubben has been named as divisional technical coordinator, Paint Division, Pittsburgh Plate Glass Co. Other appointments in the division are: **Dr. Pierson G. Boermans,** as divisional supervisor of trade sales development, **Dr. Chester G. Gauerke** as divisional supervisor of resin development and **Robert L. Nelson** as administrative assistant to **Dr. William W. Bauer,** technical director of the firm's Paint Div.

Thomas H. Brumagin has been named chief engineer of the Ajax Flexible Coupling Co., Inc.

Ray W. Patridge has assumed the position of service manager, Lebanon Steel Foundry. Mr. Patridge will be available for customer contact with regard to shop matters. **Roy W. Daub** has been named chief planning engineer at Lebanon Steel Foundry.

(Continued on next page)

news of | ENGINEERS

Lee S. Busch, research director, Mallony-Sharon Titanium Corp., has been appointed to the Sub-Committee on Heat Resisting Materials, National Advisory Committee for Aeronautics.

G. Russell Tatum has been named as general manager of Vitro Laboratories, a division of Vitro Corp. of America.

Arthur J. Burke has been appointed chief engineer, Richardson Scale Co.

J. P. Smith, formerly chief engineer of the Daven Co., has been promoted to director of engineering, and **Walter Voelker** has been appointed as chief engineer of the company.

Edward J. Charlton, manager of development engineering, Lukens Steel Co., has been made manager of fabrication at the Lukenweld Div. **Frank C. Kardevan,** present manager at Lukenweld, will join the company's field sales organization. **William H. Funk,** assistant manager of development engineering, will become acting manager of the new products development dept., reporting to the manager of Market Development.

Augustine R. Marusi, vice president in charge of Eastern operations, Chemical Div., Borden Co., has been named president of the division.

Edward L. Hart has joined Servel, Inc. as manager of civilian quality control.

Ray H. Sutter, president, has announced the purchase of the entire stock of Sutter Products Co. and the retirement of **Percy L. Sutter,** vice president. To meet expanding operations, the following appointments in personnel were announced: **Russell F. LaBeau** as executive vice president in charge of all operations; **Earl J. Blough** as chief engineer; **Oscar Bernth** as plant manager; **Seymour L. Collins** as manager of material control and customer service

Alan S. Chase has been made president of Tekwood, Inc. wholly owned subsidiary of U.S. Plywood Corp.

Dr. John D. Ryder, head of the electrical engineering dept., University of Illinois, has been named Dean of the School of Engineering at Michigan State College.

Dr. Max Bettman has joined National Carbon Research Laboratories to work in solid state physics. Other

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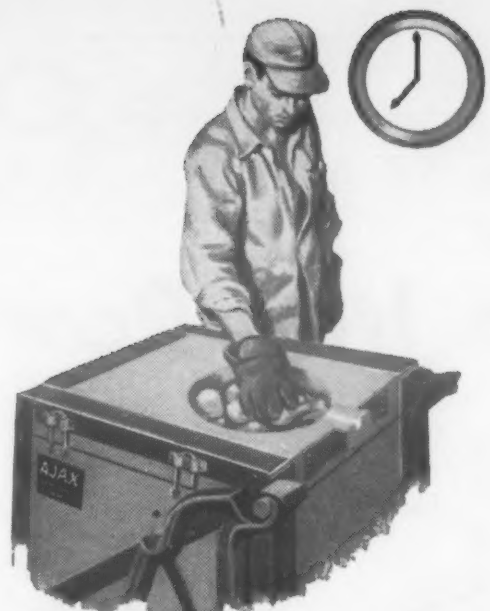
saves more than just TIME

600 lbs. of Bronze
250 Kw.

charged...



melted...

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IN JUST 25 MINUTES

Time saved . . . more heats . . . increased production are obvious benefits of AJAX-NORTHRUP Hi-Speed Induction Melting. Perhaps not so obvious, however, are many additional savings . . . important whether you have one melt a day or twenty.

The AJAX-NORTHRUP Induction Furnace melts so fast that there is practically no chance for oxidation. Without electrodes or combustion gases, there is almost complete freedom from contamination of any kind. Metal losses are virtually eliminated. Savings in even the base metals are substantial. In the costly and more easily oxidized alloying metals, savings are so large as to seem unbelievable . . . but they are true. A foundry casting 18-8 type alloys reports 100% recovery of nickel; 99% chromium; 95% molybdenum and similarly large percentages of every alloying element. A typical non-ferrous foundry reports reduced melting costs of over $33.00 a ton.

These savings can be realized in *any foundry*, ferrous or non-ferrous, providing an excellent return on your original investment in AJAX-NORTHRUP equipment.

We would be pleased to show you actual cost data that other AJAX-NORTHRUP Furnace users have made available. Just write or telephone us.

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appointments to the Laboratories include: **Dr. Earl Wesley Murbach** to work on electrochemical problems; **Dr. Karl Meyer** to do research in analytical chemistry; **Dr. Lawrence M. Litz**, and **Dr. Robert M. Broud**, to work in solid state physics.

Dr. Warren C. Lothrop has been appointed a vice president of Arthur D. Little, Inc. Dr. Lothrop will be in charge of the Research and Development Div.

George W. Russell has been named assistant general manager of American Cyanamid Co's newly formed Pigments Div.

Frank W. Glaser has been elected vice president of the American Electro Metal Corp.

George Davis and **Lowell Conrad** were appointed chief engineers, Construction Machinery Div., Clark Equipment Co.

Stanley G. Benner has been appointed to the staff of the Ceramic Coating Dept., Chemical Equipment Div., General Ceramics and Steatite Corp.

G. A. Fuchs has been made general superintendent, Fire Brick Div., Laclede-Christy Co.

Dr. Raymond B. Seymour has been named president, Atlas Mineral Products Co.

Robert R. Fink has been appointed manager of product design, Kawneer Co.

Fred H. Johnson, Leland B. Luellen and **Dr. Edwin D. Martin,** three key executives at Inland Steel's Indiana Harbor Works, will be freed of operating duties to devote full time to research programs. Fred H. Johnson, formerly chief engineer, will be assistant to the vice president in charge of steel manufacturing; Mr. Luellen, formerly assistant general superintendent, will be assistant to the vice president in charge of steel manufacturing and Dr. Martin, superintendent of research and development has been relieved of his responsibilities in order to concentrate upon a full-time research program.

Arthur H. Kirkpatrick has been promoted to the newly created position of special projects engineer, Frederic B. Stevens, Inc.

Malcolm M. Coston has been appointed manager of the Process Equipment Div., Rodney Hunt Machine Co.

(Continued on next page)


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RESISTANCE TO SCALING
MACHINABILITY
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316
430
FULLY RESISTANT
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HERE'S THE ANSWER TO FAST ACCURATE SELECTION OF STAINLESS STEELS
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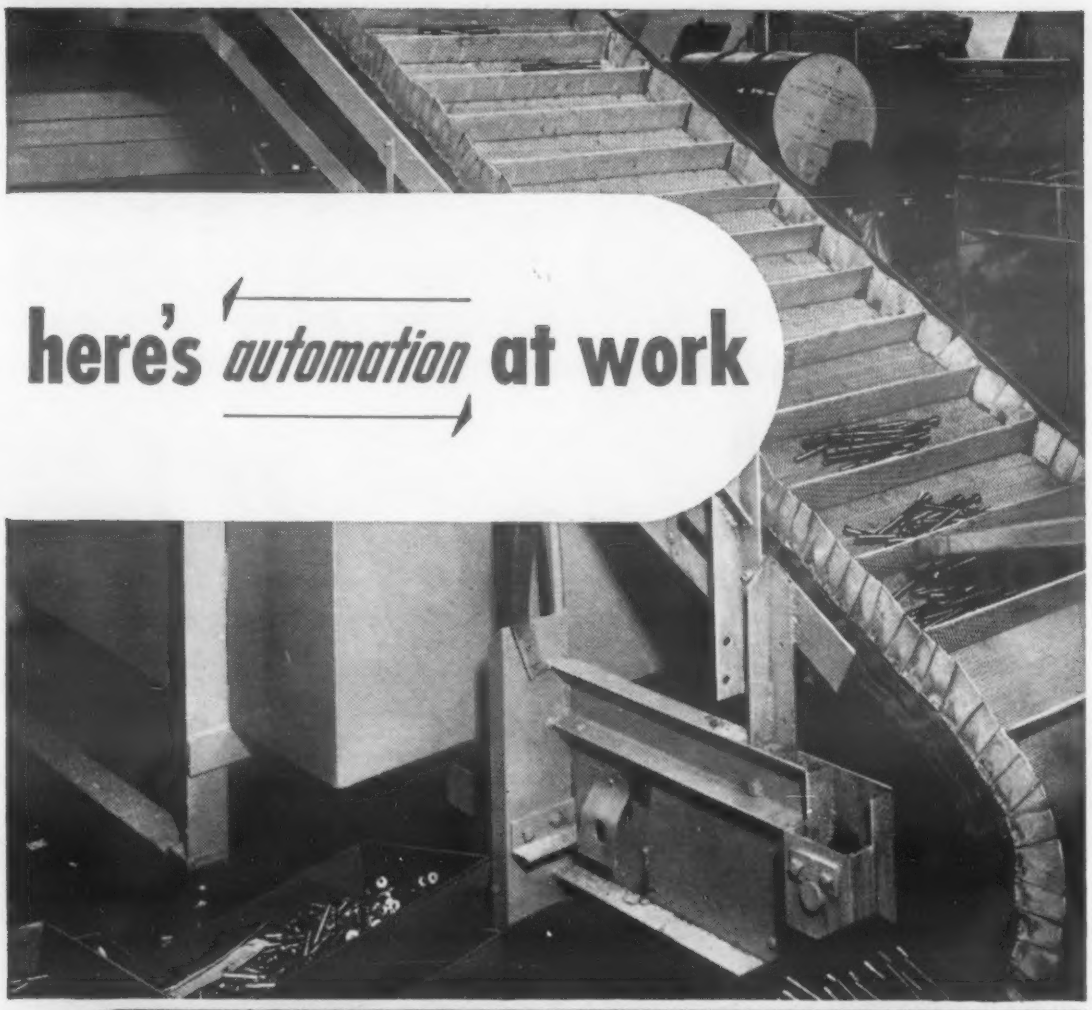


news of | ENGINEERS

Roger F. Hepenstal, vice president in charge of manufacturing for American Can Co., has been appointed to special duty with the Dept. of Defense in Washington.

Samuel N. Johnson has been named project engineer at the General Electric Chemical Materials Dept.'s phenolic products plant at Pittsfield. **Henry J. Digeser** has been named process engineer at the same plant and in the same department. **Harry S. Komer** was named superintendent of the Chemical Materials Dept.'s plant in Anaheim, Calif.

Gary Steven, expert on high-temperature metallurgy has been appointed senior metallurgist at Armour Research Foundation, Illinois Institute of Technology. **Chester A. Marcowka,** formerly with the A. O. Smith Corp., has been named a ceramic engineer in the Ceramic and Minerals Dept. Promotions of four engineers to high positions in the Heat-Power Dept. at the Institute have been announced as follows: Dr. **Henry E. Robinson,** from research engineer to senior research engineer; **Channon F. Price** from assistant supervisor to supervisor of one of the thermodynamics sections; **John C. Lee,** from assistant supervisor to supervisor of the hydraulic power equipment section, and **John P. Nordhaus,** from assistant supervisor to supervisor of the other thermodynamics section.

Died . . . Thomas R. Heyward, Jr., chairman of the board and founder of The Duraloy Co.

news of | COMPANIES

Alloy Rods Co. formally dedicated its new Pacific Coast division manufacturing plant located at 750 Lairport St., El Segundo, Calif., on Feb. 18.

Barth Stamping & Machine Works, Inc. has formally changed its name to the Barth Corp.

L. J. Mueller Furnace Co. and **Worthington Corp.** have announced jointly an agreement for the transfer of the net assets, name and goodwill of Mueller to Worthington in exchange for Worthington common

For more information, turn to Reader Service Card, Circle No. 489

stock. The Mueller plant and facilities will be operated as the Mueller Climatrol Div., Worthington Corp.

Fiber Research Corp. was organized as a Massachusetts company to undertake the commercial development of certain research activities of National Research Corp.

Shell Chemical Corp. has announced that a new epoxy resin plant in Houston, Tex. will triple the company's supply of Epon resins.

Du Pont has announced that a new pigment colors research laboratory will be built at its Newark, N.J. plant.

American Can Co. has announced breaking of ground on a 40-acre tract in Barrington, Ill., for the construction of its new Research and Development Center.

Worthington Corp. has announced that its new flexible hydraulic test laboratory has been completed and placed in operation at the Harrison Works of the company.

National Cyliner Gas Co. has announced that it will soon begin construction of a $3,500,000 plant for the manufacturing and distribution of liquid oxygen on a site located on the south side of Chicago.

Lamson Corp. has formed a new department which will specialize in the manufacture of mechanical accessories necessary for the control and operation of atomic energy power plants of all types.

Scintilla Magneto Div., Bendix Aviation Corp., has changed its name to Scintilla Div.

Librascope, Inc., a subsidiary of General Precision Equipment Corp., has announced the acquisition of the Minnesota Electronics Corp.

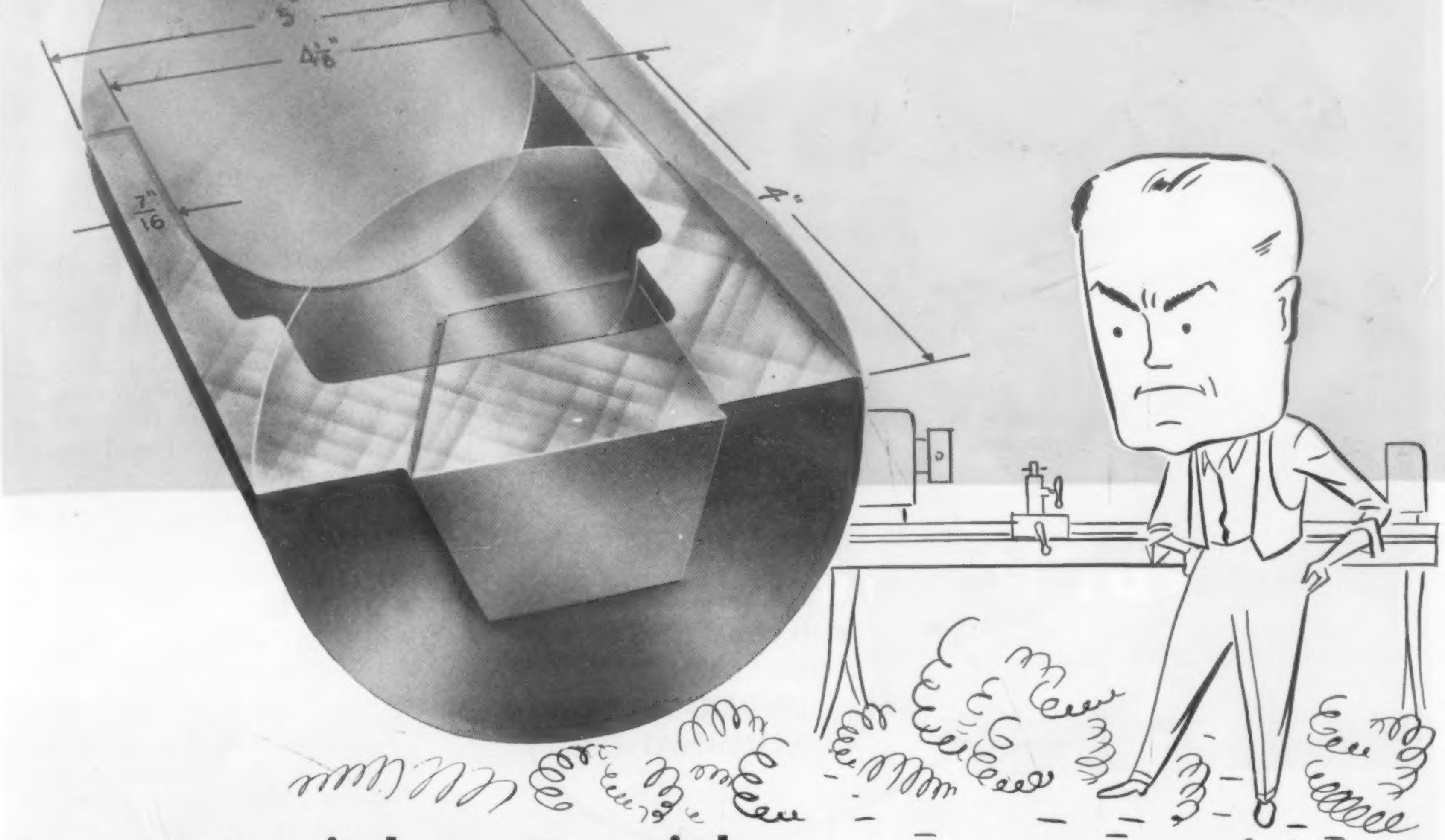
Metallizing Engineering Co., Inc., has announced plans for a new plant at Westbury, L.I., N.Y. The new building is scheduled for completion by July 31, 1954 and will occupy 65,000 square feet of a 7-acre tract.

Hanson-Van Winkle-Munning Co. has acquired the assets, customer lists, good will and personnel of the Electroplating Equipment & Supply Div., A. J. Lynch Co.

The **R. M. Reichl Co.** has been established specializing in development engineering, process-development and consulting with offices at

Mr. Production Head...

What do you waste in scrap?



Stop material waste with...

IMPACT FORGING
FROM
HIGH STRENGTH ALUMINUM ALLOYS

Think of the metal waste if the cylinder cap shown above were machined! The turnings would represent dead loss—expensive material and machining time.

By employing Hunter Douglas Impact Forging, the cylinder cap shown was produced on a mass production basis. The contoured grain flow of a forging gave great strength to resist high bursting pressures. Metal waste was practically non-existent, machining time was reduced to minor finishing operations with the resultant saving in production time.

Cold Impact Forging is a mass production technique perfected by Hunter Douglas and offering the strength and grain flow of a forging with the tolerance and precision of an extrusion. In most cases, a part is forged to final print, in every case machining operations are reduced to a minimum. For example, note in the illustration that the hexagon nut and cylinder cap were forged *in a single operation.*

Hunter Douglas has produced millions of high strength aluminum alloy impact forgings at great savings in time, cost, and material. If you are designing or producing a part calling for close tolerances and high strength, in quantities of from one thousand to one million per month, find out how Hunter Douglas Impact Forging can improve your production picture.

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news of COMPANIES

110-11 70th Road, Forest Hills, N.Y. The new company has been organized by R. M. Reichl, formerly vice president of Hydropress, Inc.

Lindberg Engineering Co.'s Detroit Office recently moved into its new modern offices at 1220 South Woodward Ave., Royal Oak, Mich.

The **Texas Plastic Development Corp.** has been organized in Houston, Tex., with Pete McNee as president and Paul W. Kollar, vice president in charge of development and production.

Torrington Manufacturing Co. has announced completion of its new Oakville, Ont. plant for its wholly-owned subsidiary, The Torrington Manufacturing Co. of Canada, Ltd.

Metallurgical, Inc. recently held open house ceremonies for its new ultra-modern metal treating plant in Minneapolis.

Adamas Carbide Corp. has moved to a new million-dollar plant at Kenilworth, N.J.

Crucible Steel Co. of America has acquired a 50 percent interest in **Vacuum Metals Corp.**, the nation's only producer of high-purity metals by the vacuum melting process. Vacuum Metals was formerly a wholly owned subsidiary of **National Research Corp.**

news of SOCIETIES

Boston College has announced a special two weeks intensive course in Modern Industrial Spectroscopy at Chestnut Hill, Boston, Mass., from July 12-July 23.

The **College of Engineering, State University of Iowa,** announces the fifteenth Management Course to be held June 14 through June 26 in Iowa City.

Drexel Institute of Technology is planning a new $1,400,000 basic Sciences Laboratories Center to be located on the block west of the existing group of Institute buildings at 32nd and Chestnut Streets, Philadelphia.

Massachusetts Institute of Technology has announced a special one-week summer program in Corrosion, to summarize the fundamental and

recent advances in this field, to be given at MIT during the 1954 Summer Session, June 21-25. A special summer program in Lubrication Engineering will also be held at MIT from June 15-25.

American Society of Tool Engineers has announced the appointment of Colonel Leslie S. Fletcher to the position of Research Fund Director.

The second award of the **K.C. Li Medal** for meritorious achievement in advancing the science of tungsten has been made to Thomas Brennan Nolan of the U.S. Geological Survey.

Illinois Institute of Technology has announced that tuition scholarships have been awarded to three metallurgical engineering students at the Institute by **Foundry Educational Foundation,** Cleveland, Ohio. The winners are Ronald B. Diamond, Fred L. Seppi, and James M. Mosby.

The **National Association of Corrosion Engineers** has announced the following 1954-55 appointments: Aaron Wachter, president; F. L. Whitney, Jr., vice president. The Association has also announced 1954 awards to Dr. Irving A. Denison to receive the Willis Rodney Whitney Award, E. H. Dix, Jr., to receive the Frank Newman Speller Award.

The **American Institute of Mining and Metallurgical Engineers** has announced that the Robert W. Hunt Award will be presented to J.F. Elliott, J. B. Wagstaff, and R. A. Buchanan for their joint authorship of a paper entitled "Physical Conditions in the Combustion and Smelting Zones of a Blast Furnace."

(Continued on next page)

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Meetings and Expositions

AMERICAN CERAMIC SOCIETY, annual meeting. Chicago. April 19-23, 1954.

AMERICAN ZINC INSTITUTE, annual meeting. St. Louis. April 20-21, 1954.

METAL POWDER ASSOCIATION, annual meeting. Chicago. April 26-28, 1954.

AMERICAN SOCIETY OF TOOL ENGINEERS, industrial exposition. Philadelphia. April 26-30, 1954.

ELECTROCHEMICAL SOCIETY, spring meeting. Chicago. May 2-6, 1954.

AMERICAN WELDING SOCIETY, exposition and national spring technical meeting. Buffalo. May 4-7, 1954.

AMERICAN FOUNDRYMEN'S SOCIETY, annual convention. Cleveland. May 8-14, 1954.

PORCELAIN ENAMEL INSTITUTE, midyear divisional meeting. Chicago. May 12-14, 1954.

INDUSTRIAL FURNACE MANUFACTURERS ASSOCIATION, spring meeting. Hot Springs. May 16-19, 1954.

BASIC MATERIALS EXPOSITION AND CONFERENCE. Chicago. May 17-20, 1954.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, spring national meeting. Springfield, Mass. May 16-19, 1954.

COPPER AND BRASS RESEARCH ASSOCIATION, annual meeting. Hot Springs. May 23-26, 1954.

AMERICAN IRON & STEEL INSTITUTE, general meeting. New York. May 26-27, 1954.

SOCIETY OF AUTOMOTIVE ENGINEERS, summer meeting. Atlantic City. June 6-11, 1954.

THE SOCIETY OF THE PLASTICS INDUSTRY, INC., national plastics exposition. Cleveland. June 7-10, 1954.

AMERICAN SOCIETY FOR QUALITY CONTROL, national convention. St. Louis. June 9-11, 1954.

MALLEABLE FOUNDERS' SOCIETY, annual meeting. Quebec, Canada. June 14-15, 1954.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Chicago. June 13-18, 1954.

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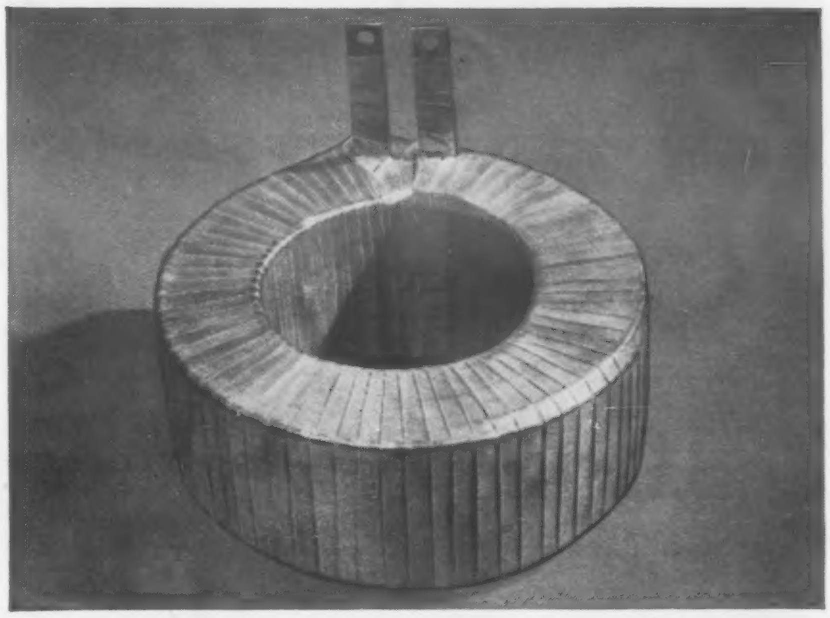
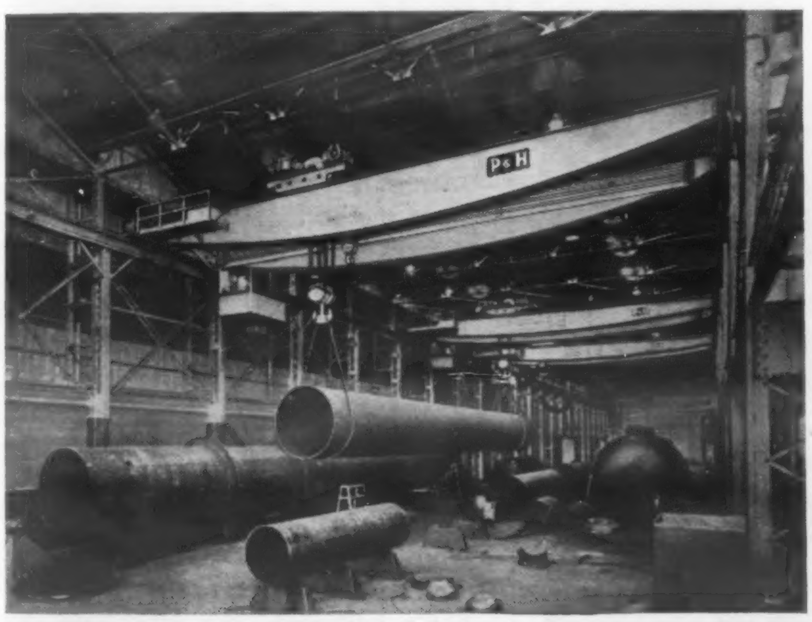
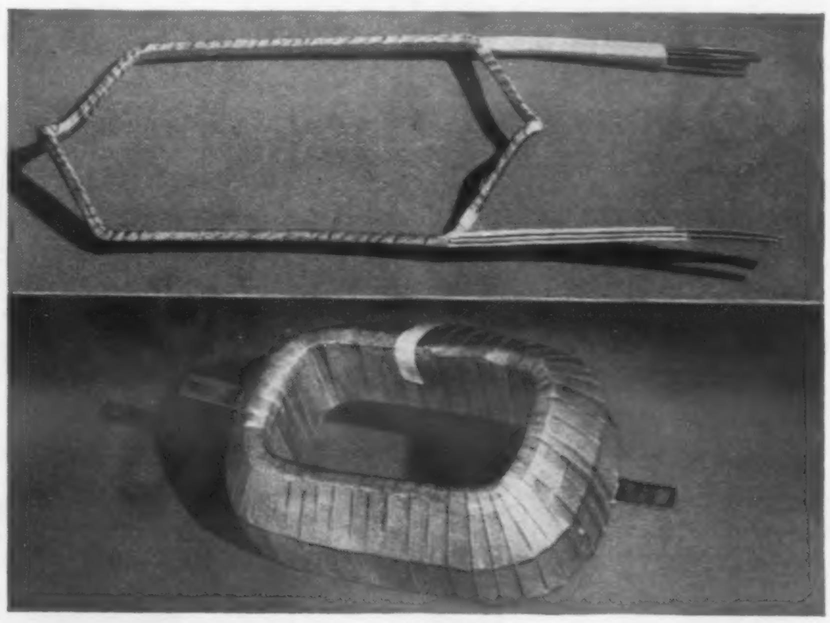
1. **Higher production from mining equipment.** Heavy excavators, such as this Harnischfeger P&H Model 1600 Electric Shovel, are designed with Class B insulation on all large d-c motors and generators, for heavier loads and longer life. Class B ISOMICA tape is used to insulate windings because of its outstanding uniformity and flexibility features.



2. **Brake coil protection with ISOMICA tape.** This d-c brake coil used in conjunction with 230-v d-c Harnischfeger Crane and Excavator Motors operating on continuous duty cycle, 75°C rise, gets premium electrical protection from ISOMICA tape. Made from long rolls of thin continuous mica sheet, this tape has no high spots or voids, gives more uniform mechanical and dielectric strength.



3. **Greater loads and longer service.** For heavy industrial work, Harnischfeger P & H Overhead Electric Cranes are sturdily built mechanically, use the strongest, most uniform electrical insulation for added performance and protection. The ISOMICA insulation, which Harnischfeger uses, is strong both mechanically and electrically ...can be wound using taping machines without breaking.



4. **Easy application, superior performance.** An armature coil and a motor field coil, both to be used in Harnischfeger Electric Cranes, are wound with ISOMICA tape made from thin continuous mica sheet. This is just one of the many specialized insulation materials developed by Mico to help manufacturers build improved performance into their electrical products.

Whatever electrical insulation material you need—Class A to Class H—standard or special—MICO makes it best. We manufacture it, cut it to size, or fabricate it to your specifications. Send us your blueprints or problems today.

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News Digest

Zone Melting

continued from page 7

concentrating all impurities in the end of the ingot, which can then be cut off and analysed. The possibility of isolating the impurity is greatly increased thereby. E. E. Schumacher, chief metallurgist of Bell Labs, claims that he and his associates are on the verge of determining the nature of the trace impurity contained in Chilean copper which makes it the only copper that can be used for certain copper-oxide rectifier applications. If this problem is solved, it may be possible to manufacture the copper with the proper trace element, and tailor it to ideal efficiency. This type of application, of course, opens up a whole field of research and development that has scarcely been touched due to the virtual impossibility of producing ultra-pure materials in any volume.

Purifies Organics

Lesser known and more recent applications of the zone melting technique include purification of organic materials such as waxes. The ordinary method of purifying such substances is fractional crystallization, which requires up to hundreds of steps with highly complex apparatus. Zone melting, according to Pfann, is capable of doing just about anything that can be done by fractional crystallization, but in much greater volume with less expenditure of time and effort, since the process is virtually wholly automatic. While inorganic materials are not ordinarily in Bell Lab's bailiwick, the labs have been doing some work on the effect of impurities and mixtures on the dielectric constants of various waxes. The inherent characteristics of ultra-pure waxes are also under examination.

Disperses Alloy Elements

Another feature of zone melting that is expected to find great use in the future is its capacity to do just the opposite of the original job for which it was conceived. It can be used to add impurities at closely controlled concentrations without segregation. It is already in use as a method of mixing precise amounts of impurities with ultra-pure germanium single crystals in order to prepare them for transitor applications (zone melting is the standard method of growing single crystals of

germanium—a seed crystal is brought in contact with the first molten zone of the ingot and the crystal grows as the zone progresses).

Undoubtedly, this remarkable and simple process will usher in many new metallurgical developments in the future. Bell's Chief Metallurgist Shumacher points out that "The goal of ultra-purity appears to be much nearer at hand for many substances. Important and sometimes drastic changes in metallic properties have already been observed as the limit of purity is approached. As more materials are brought toward this limit, there will be both opportunity and challenge to exploit their properties."

Process Now in Use

Among the developments already well underway, of course, is the remarkable progress in semiconductors. Ultra-pure copper is being investigated with profitable results. Tin, antimony and several compounds have been purified to new levels. Ultra-pure iron, which is vital for soft magnetic applications, can be produced by the zone melting process, and it is probable that it will replace the time consuming and difficult hydrogen refining technique now in use.

Perhaps the most promising aspect of zone melting is that it is not only an invaluable laboratory tool, but it is a process which can be extended to production with only a few mechanical refinements. For a four year old development, it has come a long way, and its very simplicity belies its significance to fields far removed from transistor materials, which spurred the initial development work.

ASTM Holds Committee Week

More than 1400 technical men attended the American Society for Testing Materials Committee Week held February 1 to 5 in Washington D. C. The Committees held a record 428 meetings, and announced many new specifications and tests for materials as well as numerous revisions of existing standards.

Committee Week is held so that activities of the ASTM sections will

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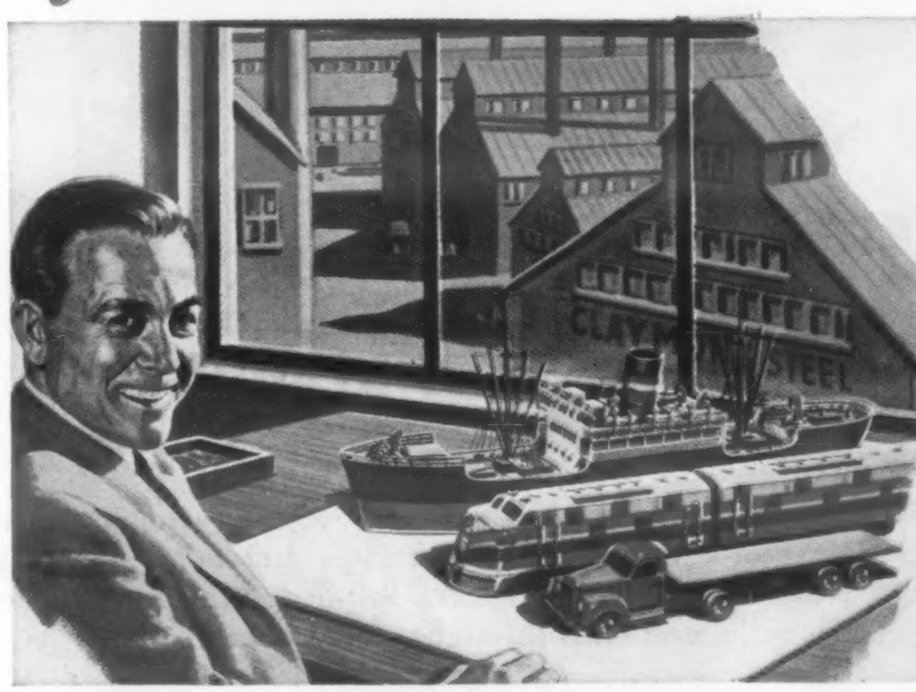

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be concentrated at one time and place so that committee members—leading engineers, scientists and educators concerned with specifications and tests—can attend a larger number of meetings with considerable savings in time and expense.

Most of the new and revised standards completed at the meetings are subject to letter ballot in the committees before they are referred to the parent society for action. In general, the new specifications will be considered finally at the ASTM Annual Meeting, to be held this year in Chicago the week of June 13.

Committee A-1: Steel

The Steel Committee reported progress in the field of mechanical testing, steel rails and accessories specifications, and specifications for structural steel for welding. The tentative methods and definitions for the mechanical testing of steel products (A 370-53T) were approved for publication. A description of special tests applicable to bolting has been approved for letter ballot. An investigation is underway to determine the usefulness and reproducibility of impact testing of steel products.

The subcommittee on forgings proposed additional yield strength measurements for generator rotors, turbine rotors and turbine wheels. Tables of chemical requirements in all tubular products specifications are to be changed to eliminate dual tables showing ladle and check analysis. A single table now covering the ranges shown as check analysis will be substituted. Proposed specifications for high strength electric fusion welded pipe for gas lines are being drawn up, and specifications are to be proposed for forged and bored austenitic steel pipe. The bar steel subcommittee is engaged in restyling all bar steel specifications, using the principle of general requirement specifications as has been accomplished for structural and pressure vessel specifications.

Proposed specifications for low alloy high tensile strength hot and cold rolled sheets are in final stages for committee approval.

Electrodeposited Metal Coatings

The committee on electrodeposited metal coatings has reversed its stand on not working out specifications for plating salts and anodes. Groups are being set up to investigate the prac-

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ticability of developing standards for this phase of electroplating work.

The committee is balloting on a revision or the practice for Preparation of High Carbon Steel for Elecplating. Revisions include electrolytic polishing among final treatment procedures. A study of tin and tin alloy coatings excluding electrolytic tin plate is expected to resolve a number of questions relating to the performance of these coatings. Problems considered will be in connection with corrosion resistance, solderability, and susceptibility to phase transformation.

Structural Sandwich Constructions

Committee C-19 discussed a proposed compression test method for cores, particularly in regard to definitions of and limitations of specimen dimensions. The test method will be revised. A test for delamination of cores has been circulated for comment and will be ready for letter ballot in the near future.

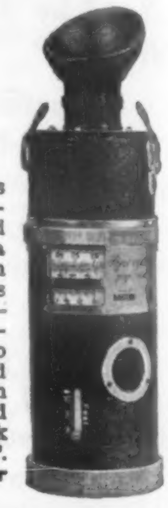
A section meeting for those interested in exposure testing devised a tentative testing plan. The work is to coincide with the exposure program and sites arranged by the Advisory Committee on Corrosion.

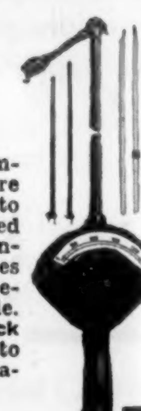
Rubber and Rubber-Like Materials

Committee D-11 and its 16 subcommittees took action on a number of new test methods and specifications. One of the most important projects nearing completion is a Glossary of Terms used in the rubber industry. The glossary, comprising some 156 single spaced typewritten pages, covers over 2000 items. Members of the committee have been requested to review the glossary for criticism and suggestions.

Methods of Testing

Committee E-1 on methods of testing held fourteen subcommittee meetings during Committee Week. A new subcommittee on Bend Testing held its organization meeting and reviewed the various types of bend tests now specified in ASTM standards. Of 151 bend test procedures specified, 137 are for metals and 14 are for nonmetallic materials. The committee decided to undertake work on the following: Correlation of bend tests now published and consideration of possible further im-





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provement and standardization; investigation of present bend test methods for possible new applications; and development of new bend test methods where needed. A set of definitions is now being drawn up covering the various types of bend tests now in use.

Definitions of terms related to mechanical testing are under consideration as to their application to both metallic and nonmetallic materials.

A method for the determination of Youngs Modulus at room temperature is in the first draft stage.

The committee participated in an organization meeting of the American Group to handle the Secretariat for the International Committee of the International Standards Organization on Determination of Viscosity. The scope of the committee is to establish the reference standards for absolute viscosity and standardization of apparatus and procedure for measuring absolute viscosity. The committee recommended for adoption by the ISO the new value of the viscosity of water of 1.002 poises at 20 C. Detailed information will be submitted to the International organization on the committee's recommendations and on the available standard viscosity samples available in this country.

Aluminum Group Holds Meeting

A new AEC has been founded which deals with aluminum, not atoms. A group of aluminum extruders have banded together in a group called the Aluminum Extruders Council, an organization which will represent the nation's independent members of the fast-growing aluminum and aluminum alloy extrusion industry.

The aluminum extrusion field is large enough to support such an organization, and industry response to a recent meeting in Cleveland drew representatives from twenty-five firms.

John Doering, president of the Council, announced one intention of the organization would be efforts to seek alleviation of tax regulations on new machinery which, he said, were "curbing the necessary expansion of

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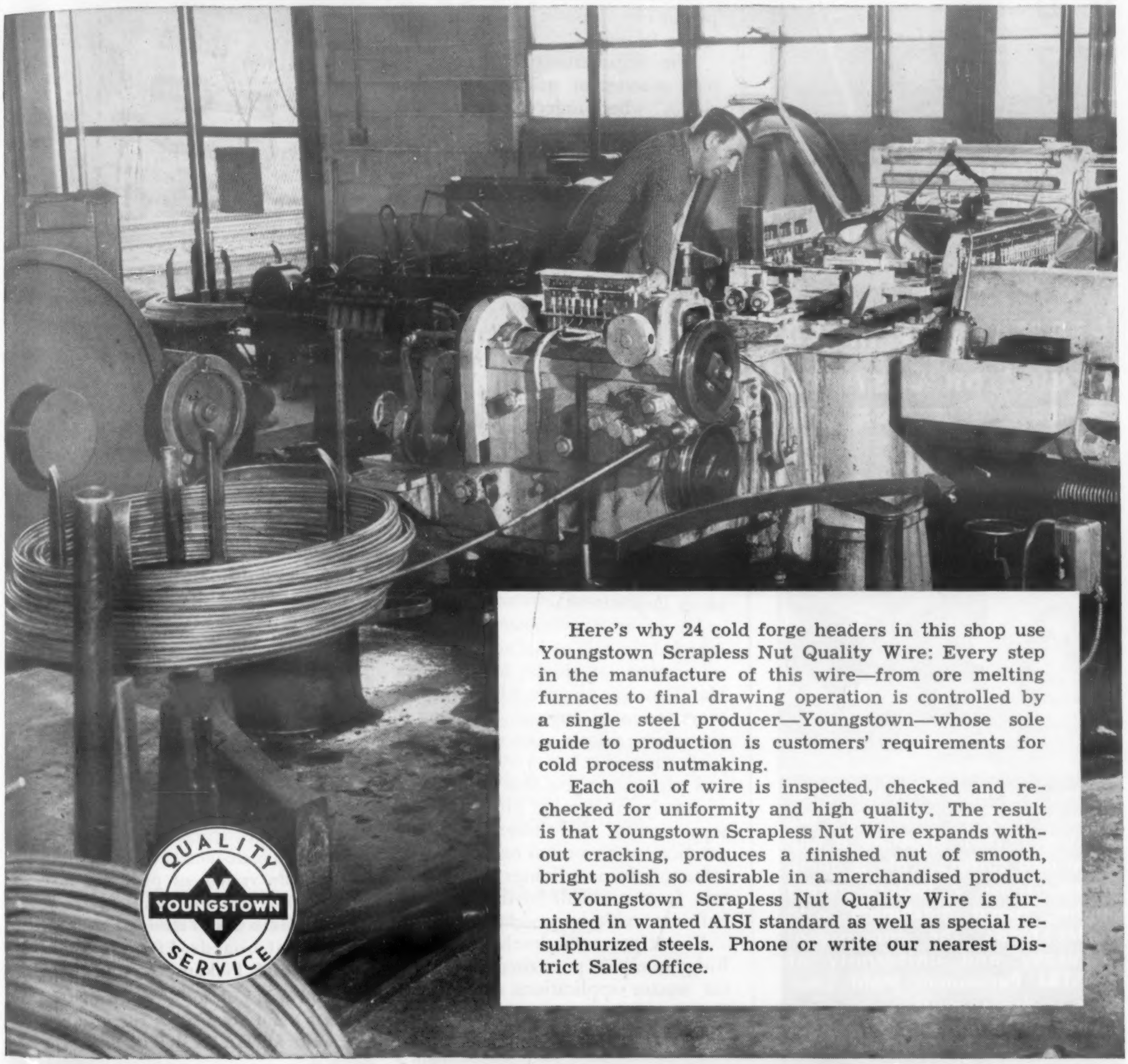

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one of America's fastest growing metals industries". He held that fast tax write offs on new equipment, similar to those in effect during the Korean emergency should be reinstituted to permit expansion of aluminum fabrication facilities.

The organization is planning to hold a series of quarterly "problem clinics" where independent extruders will be able to exchange technical information on critical production problems. The Cleveland meeting featured a problem clinic on die design problems.

Another meeting of the Aluminum Extruders Council is scheduled this month in Pittsburgh.

Hafnium Helps Refractories

Zirconia and zircon refractories may be more stable if they contain large amounts of hafnium, according to recent research undertaken by the Oak Ridge National Laboratory Ceramics Department.

For years, a mystery has surrounded the role of hafnium oxide in refractories at high temperatures. Hafnium was discovered only thirty years ago as an impurity occurring in zirconium silicate (zircon) in the proportion of 0.5 to 4.0%. Hafnium and zirconium resemble each other so closely in chemical properties that separation of the elements was impractical, so zirconium oxides used in refractory furnace linings usually contain from one half to three percent hafnium oxide by weight.

Recent processes developed at Oak Ridge to obtain pure zirconium metal for reactor applications enabled the ceramics department to obtain quantities of pure hafnium and hafnium-free zirconium. The department's staff members took advantage of the opportunity to clear up the relationship of hafnium impurities in zirconium oxide refractories.

Zirconium oxide and hafnium oxide have monoclinic crystal lattices which are practically identical, and their melting points are in the neighborhood of 5100 F. Ceramic department tests show that with one important exception, the resemblance of hafnium to zirconium continues

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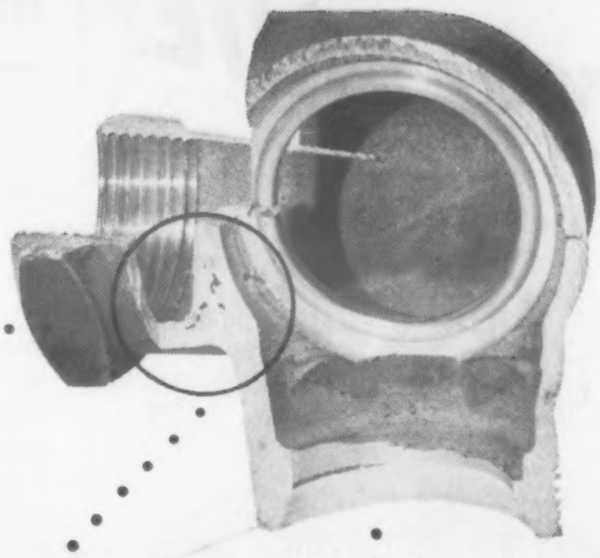

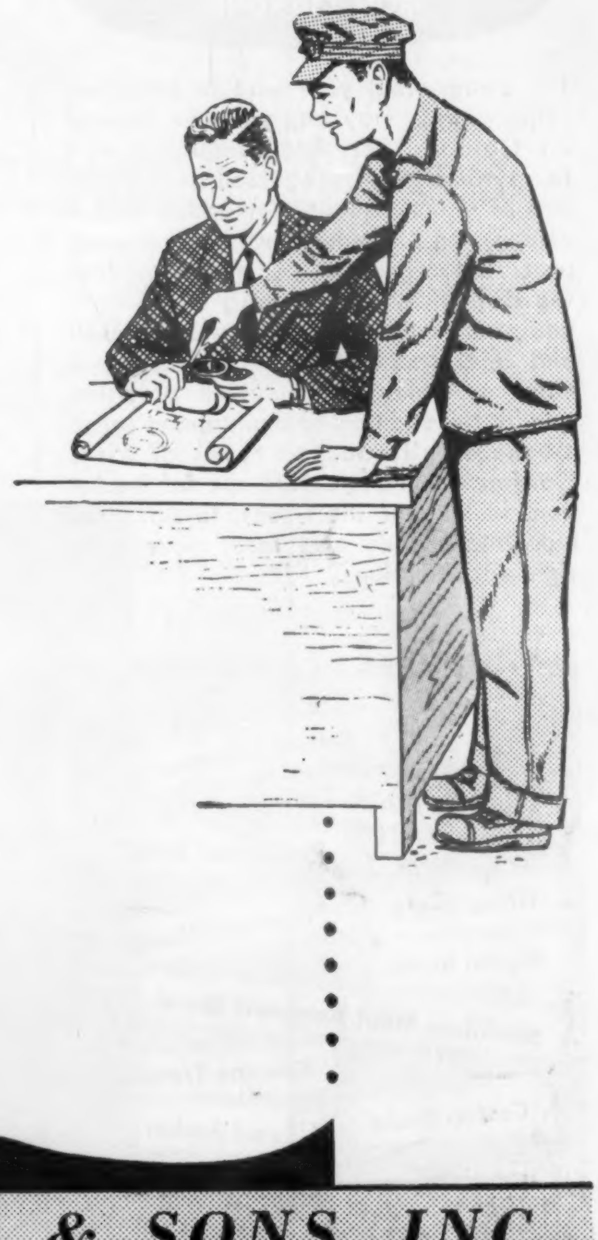

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at high temperatures. The x-ray patterns of the oxides can scarcely be distinguished from each other—the interplanar distances in hafnium oxide are smaller by only 1%. Both oxides react with silica in a solid state reaction at approximately 2700 F in a 1 to 1 molecular ratio to form a compound called zircon in one case, and hafnon in the other. The silicates are also nearly identical in crystal symmetry, x-ray properties and thermal expansion.

For use in refractories, zirconium oxide must be stabilized to overcome crystal inversions which cause shattering. The material is stabilized by heating with 3 to 8% calcium or magnesium oxide, which forms a stable solid crystal phase by solid solution. Pure hafnium oxide has a similar reaction to stabilization with calcium oxide. With 3 to 40% calcium oxide present, the monoclinic lattice of hafnia is transformed into face centered cubic crystal form. This means that in hafnia, containing zirconia stabilizations, the hafnia is also stabilized.

The notable exception to the similarity of behavior was found in the range of temperatures over which hafnium oxide and zirconium oxide are stable. The monoclinic lattice of zirconia undergoes an inversion at 1800 F to a tetragonal form. The inversion is accompanied by a large decrease in volume. The inversion is reversible, so that pure zirconia refractories tend to shatter if they are heated and cooled repeatedly. Hafnium oxide, on the other hand, remains in the monoclinic form up to 3250 F, where an inversion takes place, but it is not accompanied by such a large degree of volume change.

The tentative conclusion reached in these experiments is, therefore, that users of zircon and zirconia refractories do not have to worry about the hafnium content of the material. Indeed, in view of the greater temperature stability of the hafnium oxide and its higher melting point, it is probably desirable to seek as high a hafnium content as possible.

The ceramic laboratories at Oak Ridge, where the experiments were completed, are operated by Union Carbide for the Atomic Energy Commission.

(Continued on next page)

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Hi-Temp, Creep Courses Offered

A short course on High Temperature Properties of Materials will be held at The Pennsylvania State University between June 21 to June 25 inclusive. Following this, a course on Mechanics of Creep will be conducted between June 28 and July 2. Authorities from industrial, governmental and educational institutions will give the lectures for both courses. The programs are planned to give a broad coverage of high temperature properties of materials and mechanics of creep, and will include physical, metallurgical and design aspects. Dr. Joseph Marin, Department of Engineering Mechanics, The Pennsylvania State University, State College, Pa., is in charge of the program.

Plan to Expand Corrosion Test Sites

The ASTM Advisory Committee on Corrosion, at a meeting held recently at the site of the International Nickel Company Harbor Island Test Station at Wrightsville Beach, North Carolina, took action to expand its test site facilities.

Projected programs of the ASTM technical committees as well as a number of requests from outside interests for the use of test site space has necessitated the preparation of additional facilities at the various test site stations. Although there is at the present some unused test site space at all the sites in use, it was agreed that 110 additional racks be fabricated, 60 of monel (for marine exposure) and 50 of Type 302 stainless steel. These 110 racks will provide space for 7700 additional 4- by 6-inch specimens.

Although it was originally agreed that the Albany Committee on Corrosion would provide racks of this type only, the Committee has since modified its earlier stand to agree to consider fabricating other types of racks, provided there are strong possibilities that they can be used by more than one committee, that is, for various programs.

(Continued on next page)

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Additional pipe frames have been constructed recently or currently are being erected to provide support for the specimen racks. This includes three frames at Freeport, Texas and three at Point Reyes, California. Each frame is capable of supporting ten so-called standard racks.

New Test Programs Coming

Within the next several years, initiation of a number of test programs is anticipated. Committee A-5 on Corrosion of Iron and Steel is planning a new hardware test and it is anticipated exposure will start in the spring of 1955. These hardware specimens will be exposed at New York, Kure Beach, State College.

A special task group of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys has exposed during the past year at New York and Pittsburgh, a number of speimens designed to compare the behavior of straight chromium with chromium-nickel stainless steel.

A more extensive program of stainless steels which has been developing for a number of years is nearing the exposure stage and the actual exposure of the specimens is planned for the summer or fall of 1954.

Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys is planning to expose a number of specimens which have been stored and which were a part of the nonferrous exposure program initiated by Subcommittee VI in 1931.

Subcommittee V on Exposure and Corrosion Tests of Committee B-6 on Die-Cast Metals and Alloys put on exposure early this year at Kure beach, New York City and Columbus, a new series of tests on aluminum alloy SC84 with various amounts of zinc up to 2 per cent. These exposures are for 1- 3- 6- and 12-year periods and the specimens are in the form of ¼-in. round tension specimens.

Committee B-7 on Light Metals and Alloys, Cast and Wrought, through its Subcommittee VIII on Atmospheric Exposure Tests has initiated a program which includes 30 aluminum alloys and 8 magnesium alloys. Specimens already have been put on exposure at New York City, State College, Kure Beach, and Point Reyes. An additional series of

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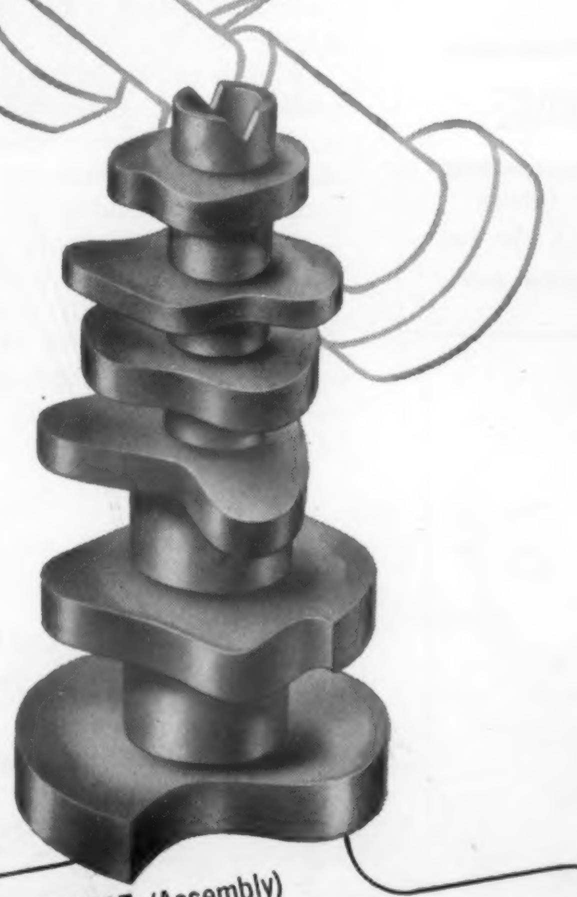

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1) Shaft — turned, drilled, faced and slotted from bar stock
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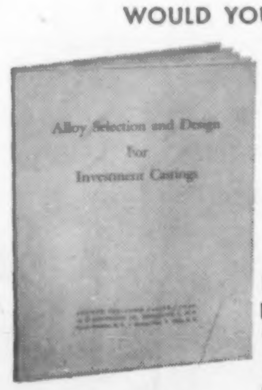

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specimens will be mounted at Freeport, Texas pending completion of racks and frames at the location. Detials of this extensive test on light metals was described in a paper by L. H. Adam on "Atmospheric Exposure of Light Metals" (available from American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. at 40 cents per copy) and which was presented at the 1953 Annual Meeting of the Society.

Committee B-8 on Electrodeposited Metallic Coatings is continuing its studies on performance tests and during the past year has exposed additional specimens of copper-nickel chromium plated specimens at Kure Beach and New York (Bell Telephone Laboratories). Also groups of 18 zinc-plated panels were exposed at Kure Beach and at the Port Authority site in New York.

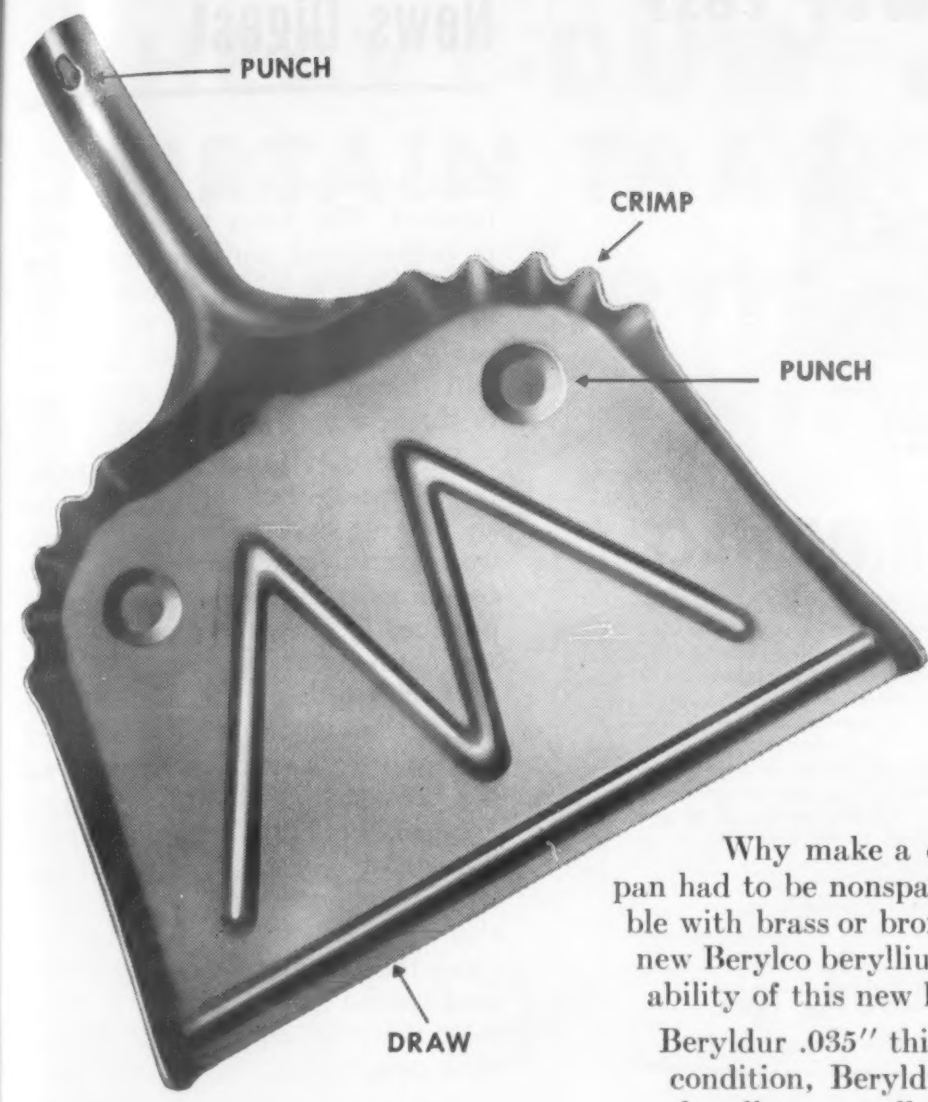
Within the next several years it is probable that Committee C-19 on Structural Sandwich Constructions, through its Subcommittee II on Performance, Durability and Simulated Service will have ready an extensive program including a wide variety of structural sandwich constructions. This work is still in the planning stage; size and shape of specimen and manner of exposure have yet to be decided.

Power Company Lays Plastic Pipe

The Carolina Light and Power Company is using a three inch plastic pipe line to conduct corrosive well water to generating facilities in its new plant in Wilmington, N. C. One of the first industrial installations of its kind, plastic pipe was selected because of its resistance to corrosion, ease of installation and low initial cost.

Installations of this type are particularly important at this time, as they will help to provide the first body of actual operational data on plastic pipe, which, although it is being used in more and more applications, has not yet been proved in terms of long range performance over a life history of many years.

The butyrate plastic pipe line, more than a quarter of a mile long, will deliver water from its source to large



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Beryldur .035″ thick was supplied in the annealed temper. In this condition, Beryldur is easy to form, as the illustration shows. The handle was roll formed and punched; the body stamped, drawn, punched, crimped and coined. The same dies used for making steel pans were employed without modification. The pan was then hardened by a simple low-temperature heat treatment to an ultimate tensile of 125,000 to 140,000 psi.

Beryldur can also be supplied in a mill-hardened temper for use when forming requirements are not severe, thus saving the cost of heat treating.

The properties of Beryldur are midway between those of high-strength and high-conductivity Berylco alloys. Beryldur therefore has higher tensile strength than brass or bronze, plus high fatigue strength, great resistance to wear, and good electrical conductivity.

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tanks where the water is to be decarbonized. The water to be conducted is air saturated and contains a high percentage of carbon dioxide. In the decarbonization process, the air and gas will be dispersed and the water will ultimately be used for all facilities of the new generating station.

Extruded of Tenite butyrate plastic, the corrosion-resistant pipe line has an i.d. of 3 in. The 20-ft lengths were joined together by slip-sleeve couplings and solvent cement which provide, in effect, welded joints. It was not necessary to thread any of the couplings or pipe. The speed with which the butyrate pipe was joined, and the ease with which it was handled, due to its light weight, made it possible to install the pipe line in less than half the time it would have taken with metal. Material costs were also considerably lower. Red brass pipe, the material originally considered for the line, would have cost almost twice as much as the butyrate plastic pipe.

The plastic pipe line will be operated at about 50 psi and is buried 30 in. below the surface of the ground. Before covering the pipe with earth the line was satisfactorily tested up to 70 psi.

The new Wilmington Steam Electric Generating Plant, where the pipe line will be used, is to be the largest in the Carolina Power and Light Company system. Two generators capable of delivering 100,000 kw or about 150,000 hp each are to be installed. Plans call for completion of the first unit in 1954 and the second in 1955.

Experimental Pump Has No Moving Parts

A vacuum pump without moving parts has been developed that is capable of producing a vacuum as high as one billionth of atmospheric pressure. The pump operates by ionizing gas molecules present in the vacuum chamber and absorbing them in carbon plates, where they stay put.

The two General Electric Scientists who developed the pump, Drs. A. M. Gurewitsch and W. F. Westendorp, say the device should simplify exhaus-

HEAVY-DUTY CURTAIN TRACK made from Cold-Formed Shapes

Bethlehem Cold-Formed Shapes can be welded without special preparation because of the smooth, relatively scale free surface.

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Curtain tracks are only one among hundreds of shapes we have turned out for such diversified items as sign-supports, rub-rails for bus bodies, and parts for lawn mowers.

Bethlehem Cold-Formed Shapes are regular or irregular shapes formed cold from strip, sheet or plate steel. They are uniform in thickness, relatively scale-free, and have a high strength-to-weight ratio. We make them on presses, brakes or rolls, in all gages from 5 to 24.

Perhaps you have an idea which could be developed into a practical, cost-cutting use for cold-formed shapes. If so, tell us about it. Write direct to us at Bethlehem, Pa., including, if possible, a rough sketch of the part you have in mind.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

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News Digest

tion of radio tubes and other widely used vacuum tubes in the process of manufacture. In addition, pumps might be permanently attached to a large tube in which a high vacuum must be maintained, as the pump is quite small and would act as an efficient getter for gasses that leaked into the pump or were given off by tube elements operating at high temperatures.

One form of the pump consists of a circular stainless steel box, about two inches in dia and an inch thick. The box is supported between the poles of a powerful Alnico permanent magnet, and is connected by means of a tube to the vessel from which gas is to be exhausted.

Inside the box is a tungsten ring, connected to the positively-charged side of the high-voltage circuit which supplies the pump. The metal walls of the box are connected to the negative side of the circuit.

Rough exhaustion of air to about one one-hundred-thousandth of an atmosphere, which is easy to attain, is accomplished with an ordinary mechanical pump.

In vacuo, high voltage causes an electron discharge from the walls of the pump. The free electrons are attracted toward the tungsten ring, but they are thrown off course by the field of the magnet and caused to perform numerous oscillations through the ring. During these oscillations, they hit and ionize many of the gas atoms present in the partial vacuum.

The ions have positive electrical charges, and are pulled toward the pump walls, which are negatively charged. On the way, the ions hit the carbon plates and are driven into them, where they are held. Since they are removed from the open space, gas pressure is reduced.

Tests show that many cubic centimeters of gas, as measured at atmospheric pressure, can be absorbed by the carbon. The absorbed gases can be driven out of the carbon, and the plates made ready to go to work again in absorbing more gas, by simply heating the whole pump.

The ionic pump works on practically all gases, and it could be used for pumping out all systems where a high vacuum is desired, including sealed-off systems; in the latter it works as a so-called "getter", to remove small remaining traces of gas.

(Continued on page 248)

NEW Viscasil

HIGH-VISCOSITY SILICONE FLUIDS

FOR NEW IDEAS IN PRODUCT DESIGN

Rate-measuring gyroscope, courtesy Doelcam Corporation

Torsional vibration damper, courtesy Houdaille-Hershey Corporation

IDEAL FOR DAMPING!

Their flat viscosity-temperature curve, stability at elevated temperatures, nearly Newtonian viscosity characteristics and ability to resist breakdown under continual high-shearing stresses make G-E Viscasil fluids ideal for all kinds of viscous dampers.

EVALUATE G-E VISCASIL FLUIDS NOW!

Now is the time to begin *your* evaluations of these new fluids. They are destined to revolutionize many current design concepts. Through them *you* may achieve simplified designs, increased product reliability and performance—even *new* products never possible before. As you "imagineer" with them, remember to free your thinking from the design limitations imposed by conventional materials. *G-E Viscasil fluids often dictate the design!*

G-E silicones fit in your future

GENERAL ELECTRIC

General Electric's new Viscasil fluids offer tremendous potential for *new* product design and *present* product improvement because of this unusual combination of properties:

- **Relatively small change in viscosity over a wide temperature range**
- **Outstanding heat resistance**
- **Outstanding resistance to shear breakdown**
- **Unusual chemical inertness and stability**
- **Compressibility — far greater than other fluids**

Available in viscosities from 1,000 to 100,000 or more centistokes, these versatile silicone fluids are ideal for such applications as:

Torsional vibration dampers
Dashpot dampers **Shock absorbers**
Fluid couplings **Servo mechanisms**
Electrical, release, pharmaceutical and cosmetic applications

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Please send me product data on G-E Viscasil fluids. I want this for ( ) Reference purposes only ( ) An immediate application on__________

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City________ Zone____ State____

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For more information, turn to Reader Service Card, Circle No. 502

News Digest

New Price Schedule For Titanium

Rem-Cru Titanium Inc. has established a new pricing system for titanium bars, billets, sheets and plates calculated on base price plus extras for size, condition, finish and quality. Previous prices have been quoted on an item basis; that is, a certain price for a particular gauge in a standard size sheet. The new system is similar to those used in pricing other finished metals.

The price of sponge has not changed and remains at $5.00 per pound. However, Rem-Cru's new listing shows price reductions ranging up to 14% for some titanium billets and bars.

The price reduction for titanium reflects the metal's rather peculiar position in the light of long and short range demand for the new metal. Most of the really large volume figures on titanium use are future projections based on drawing board estimates—particularly in the aircraft field. Currently, actual consumption of the metal is lagging slightly behind production, which is hardly surprising, considering the high price and predictions of future shortages of the material when new defense demands may swallow all the available supply. Price concessions may be the answer to getting the temporary titanium surplus used up.

Other Available Literature

Irons and Steels • Parts • Forms

Metal Products. Allied Metal Specialties, Inc., 4 pp, ill. Profusely illustrates a variety of trays, racks, fixtures, tanks, crates, baskets, etc. produced by this company. (51)

Carbonyl Iron Powder. Antara Chemicals, Div. of General Dyestuff Corp., 31 pp, ill. Description, use and formulation of high purity carbonyl iron powders for electronic and powder metallurgy use. (52)

Wire Parts, Small Metal Stampings. Art Wire & Stamping Co., 4 pp, ill. Profusely illustrates a variety of wire parts and small metal stampings produced in both ferrous and nonferrous metals. (53)

Precision Castings. Austenal Laboratories, Inc., Microcast Div., 16 pp, ill. Describes Microcast Process for manufacture of precision cast parts, including specifications and explanation. (54)

Cold-Formed Steel Shapes. Bethlehem Steel Co. Booklet illustrates various types of cold-formed steel shapes made from strip, sheet or plate, giving their features and possible applications. (56)

Welded Steel Tubing. Brainard Steel Co., Tubing Div., 8 pp, ill. Shows facilities for manufacturing welded steel tubing, its applications, fabrication and specifications. (57)

Stainless Steel Forms. G. O. Carlson Inc., 4 pp, ill, No. 625. Revised bulletin features high quality stainless steel plates, heads, disks, rings, forgings, bars and sheets (No. 1 Finish) produced by this company. (59)

Spun Shapes. C. A. Dahlin Co., 4 pp, ill. Offers facilities for the metal spinning of almost any metal or alloy, specializing in stainless steel. (61)

Gray Iron Castings. Dostal Foundry Machine Co. Permanent mold gray iron casting facilities. (62)

Springs, Wire Forms, Stampings. Dudek & Bock Spring and Mfg. Co., 3 pp, ill. Shows springs designed in coil, wire forms and metal stamping forms designed and manufactured to meet specification requirements. (64)

Corrosion Resistant Castings. The Duraloy Co., 16 pp, ill, No. 3150-G. Describes facilities for manufacture of chromium-iron and chromium-nickel castings. Gives detailed properties of alloys and their uses. (65)

Investment Castings. Engineered Precision Casting Co., 8 pp, ill. Complete data on EpCo precision investment castings of stainless steel, alloy tool steel, beryllium-copper and most metals that can be melted. (66)

Aluminum and Stainless Steel Parts. Falstrom Co., 4 pp, ill, Nos. 140 and 141. Fabrication of parts, components and equipment from aluminum and stainless steel sheet. (67)

Centrifugal Cast Tubing. Peter A. Frasse Co., 17 pp, No. 11. Covers in detail the characteristics, properties, analyses, applications on Acipco centrifugal cast tubing. (68)

Metal Stampings. Geuder, Paeschke & Frey Co., 12 pp, ill. Detailed description of this firm's metal fabricating, finishing and assembling facilities as a subcontractor for defense parts. (69)

Stainless Steel Equipment. Rodney Hunt Machine Co., 4 pp, ill, No. 153. Shows the range of engineered stainless steel equipment produced by this company, from small vessels to complex fabrications—featuring tanks of standard and special construction. (72)

Permanent Magnets. Indiana Steel Products Co., 8 pp, ill, Vol. 1, No. 2. "Applied Magnetics" features two brief articles on permanent magnets. (74)

Plate and Sheet Metal Products. Littleford Bros., Inc., 8 pp, ill, No. MP-39. Profusely illustrates a complete line of plate and sheet metal products fabricated by this company. (76)

Clad Steel. Lukens Steel Co. Conversion tables and theoretical weights for clad steel plate conveniently assembled on a new information card. (77)

Ductile Iron Castings. Lynchburg Foundry Co., 12 pp, ill. Describes ductile cast iron with detailed description of its properties and suggested applications. (78)

Welded Assemblies. The R. C. Mahon Co., 1 p, ill. Shows several examples illustrating the capabilities of welding for construction of various assemblies. (79)

Sheet Metal Products. Maysteel Products Inc., 10 pp, ill. Illustrates Maysteel's standard and specialized tools for producing sheet metal parts and shows some of the industries served by their products. (80)

Metal Powders. Plastic Metals Div., 4 pp, ill, No. 567. Describes applications, advantages and limitations of powder metallurgy as used by this firm for custom making parts. (83)

Metal Powder Machine Parts and Bearings. Powdercraft Corp., 4 pp, ill. Detailed specifications of a complete line of Powdercraft self-lubricating bearings and machine parts produced by powder metallurgy. (84)

Stainless Steel Cable. John A. Roeblings' Sons Co., 4 pp, ill. Case histories showing advantages of this company's Aircord, said to have high strength, great flexibility and small diameter. (87)

Precision Investment Casting. Alexander Saunders & Co., 12 pp, ill. Advantages in comparison with conventional methods of producing precision investment castings, technique, and equipment and supplies needed. (88)

Stainless Steel Products. Schnitzer Alloy Products Co., 64 pp, ill, No. 54. A guide and reference book covering a complete line of stainless steel products produced by this company. (89)

Magnet Wire. Sprague Electric Co., 4 pp, ill, No. 404. Complete data on Ceroc ST, a single-teflon, ceramic insulated high temperature magnet wire. (90)

Deep-Drawn Shapes. Roland Teiner Co., 8 pp, ill. Reprint illustrates the many deep-drawn simple and intricate shapes produced by the new Hydroform process. (91)

Precision Casting. Thompson Products, Inc., Metallurgical Products Div., 8 pp, ill, No. MP-53-1. Discusses the Intricast process of precision casting any castable metal or alloy. (92)

Cylinder-Finish Tubing. Tube Reducing Corp., 4 pp, ill, No. R-7. Illustrates close tolerances and good surface finish obtained in compression formed tubing. (95)

Centrifugal Cast Parts. United States Pipe and Foundry Co., 12 pp, ill. Describes centrifugal castings process and advantages, and shows three applications improved by this method. (96)

Screw Machine Parts and Other Metal Forms. Worthington Corp., 7 pp, No. W-350-B5C. Describes valves, flanges, hose nipples, bars, welding electrodes and screw machine products available. (100)

Sintered Alloys. Yale & Towne Mfg. Co., American Sintered Alloys Div. Discusses the use of sintered alloys for gears, which results in saving money and easing other problems such as metal procurement, scrap waste and small parts inventory. (101)

Nonferrous Metals • Parts • Forms

Aluminum Castings. Acme Aluminum Alloys Inc., 16 pp, ill. Pictures the many facilities of this company for producing a variety of castings, tools and related products. Technical data included. (105)

Precision Die Castings. Advance Tool and Die Casting Co., 3 pp, ill. Gives physical composition and average properties of zinc and aluminum alloys and illustrates some of the facilities for producing die castings. (106)

Aluminum Coiled Tubing. Aluminum Co. of America, 8 pp, ill, No. AD-270. Gives advantages, applications, installation procedure and technical data of Alcoa Utilitube, an aluminum coiled tube made of the alloy B50S. (107)

Zinc Die Castings. American Die Casting Institute. Bulletin describes Certified Zinc Alloy Plan, explaining benefits to die casting buyers. (108)

Plastics Selection. American Insulation Corp. Disk-shaped dial card gives physical properties of the 15 most popular plastics to aid in selecting proper plastic. (109)

Bronze Casting Alloys. American Manganese Bronze Co., 50 pp, ill. Revised edition gives composition, characteristics and applications of the principal copper alloys used to make castings. (110)

Zinc Anodes. American Zinc Institute, 30 pp, and 35 graphs. Cathodic protection with zinc anodes. Supplements the report "Zinc as a Galvanic Anode". Includes field test data on zinc anode performance over ten-year history. Case histories and design information with many charts. (112)

Precision Investment Castings. Arwood Precision Casting Corp., 16 pp, ill. Informative article on precision investment castings. Includes table of ferrous and nonferrous alloys recommended as most adaptable for this process. (113)

Precision Castings. Atlantic Castings and Engineering Corp., 12 pp, ill. "High-Quality Precision Castings for Industry" illustrates Atlantalloy casting process, gives specifications and describes all specified metals, their characteristics and uses. (114)

MANUFACTURERS' LITERATURE

Titanium. Brush Laboratories Co., Div. of Clevite Corp., 4 pp, ill, No. 804. Complete data on titanium fabrication facilities. (116)

Bronze Bearings. Bunting Brass & Bronze Co., 64 pp, ill, No. 152. Pocket-size booklet contains complete list of industrial standard stock bearings, electric motor bearings and precision bronze bars. (117)

Cemented Carbide Products. Carboloy Dept., General Electric Co., 60 pp, ill, No. GT-250. Specifications and applications of this company's cemented carbide tools and blanks, both standard and made to order. (118)

Pre-Coated Metal Strip. Coated Coils Corp., 3 pp, ill. Versatile color finishes produced by an exclusive process is illustrated by actual sample of Enamelstrip, the metal coil pre-coated in color. Address inquiries to Mr. Marvin Richfield, Adv. Mgr., 513 W. 30th St., New York, N.Y.

Magnesium and Aluminum Castings. Eclipse-Pioneer Div. Foundries. "Book of Facts" shows company's facilities for custom-making aluminum and magnesium castings. (119)

Metal and Plastics Parts. The Electric Autolite Co., Bay Mfg. Div., 16 pp, ill. Shows wide variety of custom-made ornamental and functional metal and plastics parts. (120)

Die Cast Parts. The Electric Auto-Lite Co., Die Casting Div., 16 pp, ill, No. G137. Describes facilities for economical manufacture of quality die castings. (121)

Investment Castings. Electronicast Inc., 4 pp, ill. Features specifications of the Electronicast process of centrifugal and vacuum investment casting for casting difficult alloys in intricate shapes and to extremely close tolerances. (122)

Copper and Brass Tubing. H & H Tube and Mfg. Co., 4 pp, ill. Describes seamless braze and lock seam tubing copper and brass. (124)

Nickel-Base Alloys. Haynes Stellite Div., Union Carbide and Carbon Corp., 40 pp. Properties, specifications and uses of Hastelloy corrosion resistant grades. (125)

Die Castings. Hoover Co., 12 pp, ill, No. 853. Shows this company's facilities for producing zinc and aluminum die castings. Includes design helps, describes applications. (126)

Beryllium-Copper Electronic Components. Instrument Specialties Co., Inc., 8 pp, ill, No. 7-A. Includes specifications of a complete line of micro-processed electronic components of beryllium-copper. (127)

Bronze Parts. Johnson Bronze Co., 106 pp, ill, No. 530. Catalog listing quality bearings, bar bronze, babbitt and powder metallurgy products. (128)

Gaskets. Lead Alloy Products Co., 4 pp, ill. Lead clad copper seals combine ductility and strength. (129)

Die Castings. Litemetal DiCast, Inc., 12 pp, ill. How to select best light metal for die casting. Shows facilities producing light metal pressure die castings. (130)

Titanium and Its Alloys. Mallory-Sharon Titanium Corp., 16 pp, ill. Current data on the properties of various grades of titanium and titanium alloys. (131)

Precision Castings. Ohio Precision Castings Inc., 12 pp, ill. Numerous examples of industrial applications of this company's brass, bronze, aluminum and beryllium-copper plaster mold castings. (132)

Die Castings. Paramount Die Casting Co., 4 pp, ill. Facilities of this company for producing aluminum, magnesium and zinc die castings. (133)

Titanium and Its Alloys. Republic Steel Corp., 32 pp, ill, No. 588. A practical working manual presenting some basic and fairly well substantiated data on commercial quality titanium and its alloys. (134)

Lockseam Tubes. Revere Copper and Brass, Inc., 46 pp, ill. Contains comprehensive listing of more than 100 shapes of lockseam tube and rolled moldings of interest to manufacturers in the automotive, house furnishings, hardware and farm implement fields. (135)

Aluminum Mill Products. Reynolds Metals Co., 12 pp, ill, No. G1-8.5-852. Outlines increasing advantages of wrought aluminum alloys, lists Reynolds aluminum mill products, and details various products forms, finishes, alloys, tempers and sizes available. (136)

Spun Metal Parts. Spincraft Inc., No. 3. Data book on metal spinning and fabricating gives data on process and help in designing for economical production. (138)

Aluminum and Stainless Steel. Superior Industries Inc., 14 pp, ill, No. 53-A. Description of Artrim precision extrusions of aluminum and stainless steel for decorative use. Describes facilities for special shape extrusions. (140)

Tungsten Electrodes. Sylvania Electric Products Inc., 2 pp, ill, No. TC-1. Advantages, sizes, surface finishes, tempers and packing and distribution of tungsten electrodes for atomic hydrogen, helium and argon arc welding. (141)

Die Castings. Tri-State Die Casting Corp. New folder describes this company's facilities for production of aluminum and zinc die castings to order. (142)

Nonferrous Castings. The Wellman Bronze and Aluminum Co., 16 pp, ill, No. 50. Characteristics, typical uses and specifications of Well-Cast magnesium, aluminum and copper-base alloys. (143)

Centrifugal Castings. Wisconsin Centrifugal Foundry Inc., 4 pp, ill. Technical data on nonferrous machined products centrifugally cast and centrifuged for aircraft, diesel engine railroad maintenance, machine tools, earthmoving machinery. (144)

Spun Tubing. Wolverine Tube Div., 28 pp, ill. Advantages and numerous applications of this firm's nonferrous Spun End Tube Process. (145)

Light Metal Forgings. Wyman-Gordon Products Corp., 4 pp, ill. Announces the availability of large-size light alloy forgings, particularly those of magnesium and 75-S aluminum. (146)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on pages 261 and 262

Nonmetallic Materials • Parts • Forms

Honeycomb Material. Aircomb Section, Douglas Aircraft Co., Inc. Announces the development of Aircomb, a honeycomb structure of Kraft paper impregnated with a phenolic resin. Pre-cut in any thickness from 1/16 to 5 in., it is said to be 16 times as rigid as an equal weight of steel, durable, fire-resistant, pest-resistant and has excellent insulation and soundproofing properties. (149)

Thermosetting Plastics. American Cyanamid Co. Thirty success stories show outstanding sales advantages of using Cyanamid plastics, which are hard-wearing, hard-surfaced and hard-to-break. (150)

Rigid Polyvinyl Chloride. American Lucoflex Inc., 16 pp. Complete technical data on Lucoflex, a nonflammable, unplasticized polyvinyl chloride plastic, having outstanding thermal, chemical and physical properties. (151)

Extruded Plastics. Anchor Plastics Co., 12 pp, ill. Applications of thermoplastic rods, tubes and shapes. Summary of properties of plastics materials with usage table. (152)

Corrosion Proof Cements. Atlas Mineral Products Co., No. 5-1. Handy charts cover a complete line of resin, sulfur, silicate and asphaltic cements, and show how to select the correct cement for a specific application. (153)

Polyester Resins. Atlas Powder Co., 10 pp. Describes uses, physical properties and general characteristics of Atlas 100% alkyd-type resins. (154)

Gaskets, Packings, Etc. Auburn Mfg. Co., 3 pp, ill. Discusses the various products produced by this company, including gaskets, packings, washers, spacers, seals, shims and bushings. (155)

Adhesives, Coating, Etc. Chemical Development Corp., 12 pp. Discusses a variety of adhesives, protective and strippable castings, and anti-static and cleaning solutions for use in the plastics and allied industries. (156)

Plastisol. Chemical Products Corp., 8 pp, ill. Chem-O-Sol thermosetting plastisol formulation for industrial and consumer products. Instructions for use and several case histories of coated products. (157)

Engineered Paper Products. Cincinnati Industries Inc., 16 pp, ill. Complete data on the new double crepe Cindus material called X-Crepe that can be used like cloth, instead of rubber, in place of cork, and for jobs where no other material will do. (158)

Coated Fabrics. The Connecticut Hard Rubber Co. Uses, chemical, electrical and mechanical properties, and availability of heat resistant silicone rubber coated glass fabrics. (159)

Molded and Extruded Rubber. Continental Rubber Works, 8 pp, No. 100. Gives dimensions of molded and extruded rubber with cross sectional illustrations. Also condensed SAE and ASTM specification chart. (160)

Impregnated Materials for Reinforced Plastics Molding. Cordo Molding Products Inc., 3 pp, CMP-GI. Description of formulations available for molding products of reinforced plastics. (161)

MANUFACTURERS' LITERATURE

Plastic. Crane Packing Co., 12 pp, ill, No. T-103. Complete data on Chemlon packings and gaskets fabricated from the new tetrafluoroethylene resin, Teflon. (162)

Plastic Bearing Material. Dixon Saddle Co., 2 pp. Typical properties of Rulon, a plastic bearing material that requires no lubrication. (163)

Resin-Coated Glass Fabrics. E. I. du Pont de Nemours & Co. (Inc.), Fabrics Div., 4 pp, No. A-5401. Properties and applications of Teflon tetrafluoroethylene resin-coated glass fabrics, tapes and laminates. (165)

Vinyl Resins. Firestone Plastics Co., Chemical Sales Div., 17 pp. Description and physical properties of Exon vinyl resins. Also test procedures to determine volatile matter, relative viscosity and heat stability. (166)

Cast Wood. Forestrong Co., 4 pp, ill. Profusely illustrates and describes a wood fiber molding process. (167)

Setting Compound. Furane Plastics Inc., 1 p, No. A-2-52. Data on Furane Resin X-2, in conjunction with activated silica, which forms a remarkably fast setting compound. (168)

Plastic-Faced Plywood. Georgia-Pacific Plywood & Lumber Co., 4 pp, ill. Applications, properties and description of GPX high grade exterior plywood coated with plastic. (169)

Insulating Sheet. Glastic Corp., ill. Property data and comparison charts on Glastic MM, Fiberglas reinforced laminate with high strength and heat resistance for electrical insulation. (170)

Vibration Eliminator. B. F. Goodrich Co., 4 pp, ill, No. 7290. Includes installation instructions of the Goodrich Vibropad, which muffles shock, noise and vibration of heavy equipment. (171)

Polyvinyl Chloride Resins. B. F. Goodrich Chemical Co., 16 pp, ill, No. G-8. Bulletin discusses the materials and factors used in calendering, extrusion and injection molding compounds. (172)

Resin-Rubber Material. Goodyear Tire & Rubber Co., Chemical Div., 24 pp, ill, No. S-9492. Detailed tabular data on Pliolite S-6B, a thermoplastic resin for use in the manufacture of rubber products. (173)

Plastics. Heil Process Equipment Corp., 3 pp, ill, Nos. 752, 753 and 754. Discusses the use of Rigidon plastics exhaust heads, duct fittings and ventilating ducts. Specifications included. (174)

Rigid Polyvinyl Chlorides. Kaykor Industries Inc., Div. of Kaye-Tex Mfg. Corp., 6 pp. Chemical and physical properties of Vyflex rigid polyvinyl chloride plates and sheets. (175)

Fluorocarbon Plastics. M. W. Kellogg Co., 16 pp, ill. Index of processors and converters, manufactured items and services connected with the production of Kel-F parts and forms. (176)

Furfuryl Alcohol Resin. Maurice A. Knight Co., 4 pp, ill, No. 6. Properties, uses and applications of Permanite alcohol resins used in the fabrication of corrosion-proof chemical equipment. (177)

Compression Molded Plastics. Kuhn & Jacobs Molding & Tool Co., 10 pp, ill, No. E-604. Illustrates the facilities of this company for producing compression molded plastics. Includes specifications. (178)

Glass. Libbey-Owens-Ford Glass Co., 8 pp, ill, No. SPD. Describes a variety of types of glass for decorative and functional purposes, giving typical uses, properties and available sizes. (179)

Plastics Molding. P. R. Mallory Plastics, Inc., 4 pp, ill. Complete production facilities for large scale production of custom-molded parts from design to finishing and assembly. (180)

Carbon Products. Morganite Inc., 8 pp, ill, No. 1f. Specifications of various carbon bearings and bushings. Also properties of six series of Morganite carbon products. (182)

Glass Bonded Mica. Mycalex Corp. of America, 24 pp, ill. Design information for parts to be machined from glass bonded mica. (183)

Laminated Plastics. National Vulcanized Fibre Co., 16 pp, ill, No. 1b/12. Physical, electrical, mechanical and chemical properties of Phenolite laminated plastic sheet, rods, tubing and special shapes. Properties of National Vulcanized Fibre also listed. (184)

Molded Rubber Parts. Parker Rubber Products Div., Parker Appliance Co., 4 pp, ill, No. 5201A1. Lists the many advantages of using Parker custom molded rubber parts in a variety of applications. (185)

Fiber Glass. Pittsburgh Plate Glass Co., of Weldesign" explains how to shape steel for low cost, using Lincoln's Weldesign methods. (186)

Extruded and Molded Rubber Parts. Republic Rubber Div., 12 pp, ill. Describes facilities for custom manufacture of molded and extruded rubber products. Lists various products. (187)

Fluorocarbon Plastics. Resistoflex Corp., Fluoroflex-T assures the ideal, low loss insulation for uhf and microwave applications and serviceability through temperatures from —90 to 500 F. (188)

Laminated Phenolics. Rogers Corp. "Here's Rogers and Its Fiberloys" describes Rogers Corp. and its laminated phenolics, vulcanized fibres and paper boards. (189)

Extrusion of Plastics. Sheffield Plastics, Inc., 2 pp, ill. Describes custom service for producing rods, tubes and other thermoplastics shapes to order. (190)

Sponge Polyvinyl Chloride Plastic. Sponge Rubber Products Co., 3 pp, ill. Outstanding features, physical properties and chemical resistance of unicellular polyvinyl chloride plastic. (191)

Carbon and Graphite Parts. Stackpole Carbon Co., No. 40. Shows numerous standard parts and includes helpful data on the selection of carbon-graphite products. (192)

Ceramic Products. Stupakoff Ceramic and Mfg. Co., 52 pp, ill, No. 951. Drawings and dimensions of more than 500 steatite products, chart of technical characteristics of Stupakoff ceramics, and standards for steatites. (193)

Vulcanized Fiber and Laminated Plastics. Taylor Fiber Co., 4 pp. Basic properties of plastic laminates and vulcanized fibrous materials arranged in convenient tables. (194)

High Temperature Insulation. H. I. Thompson Co., 34 pp, ill. Detailed technical data on Refrasil, giving case histories on performance characteristics as a high temperature insulator. (196)

Rubber Products. U. S. Rubber Co., 25 pp, ill, No. M-9012. Detailed description of new research and development laboratory, indicating its place in development of rubber products. (197)

Synthetic Rubber Products. Western Felt Works, Acadia Synthetic Products Div., 6 pp, ill. Describes various types of molded, extruded, roll die cut and lathe cut synthetic rubber parts and sheets. (198)

Nonmetallic Gears. Westinghouse Electric Corp., 15 pp, ill, No. B-4661. Description and applications of Micarta gears. Includes tables of properties, gear data and preferred pitches. (199)

Finishes • Cleaning and Finishing

Zinc, Cadmium Finishes. Allied Research Products Inc. Describes Iridite, finishes for zinc and cadmium in chromium-like, olive green, iridescent and other colors. (201)

Cleaning Cabinets. American Wheelabrator & Equipment Corp., 28 pp, ill, No. 724. Describes Wheelabrating cleaning process and equipment used to meet specific requirements of cleaning and finishing problems of various industries. (202)

Hard Facing. Cleveland Hard Facing Inc., 4 pp, ill. Service for hard facing parts subject to intense wear conditions. (203)

Spray Painting. Conforming Matrix Corp., 5 pp, ill. Gives description, uses and advantages of this firm's spraying masks, mask washing machine, and spray painting equipment. (204)

Magnesium Finishing. Dow Chemical Co., Magnesium Dept., 128 pp. A revised edition of the manual on finishing systems for magnesium products. (205)

Industrial Cleaning. Du Bois Co. Metal cleaning chart with folder on three-stage spray cleaning and a spray booth maintenance check chart. (206)

Air Dry Lubricant. Electrofilm Corp., 4 pp, ill. Complete data on Lubro-bond, a dry film lubricating compound specifically designed to meet the anti-friction requirements of industry. Prices included. (207)

Acid Derusting and Descaling Compound. Enthone Inc., 3 pp. Detailed information on Enthone Descaler 2A, a dry, freeflowing acid compound used for removing rust and scale from steels and alloy steels. Prices included. (208)

Baked Enamel. The Glidden Co., 12 pp, ill. Nebelon-S, a high hardness, stain resistant, flexible baked enamel finish. (209)

Film Clear Resin Coating. R. M. Hollingshead Corp. U. S. Army specification 3-182 gives usage, application, protection, price, etc. on a thin film clear resin coating. (210)

Wax Finishes. S. C. Johnson & Son, Inc., 16 pp, ill, No. ADV 322. Brief description of wax finishes for such materials as rubber, metals, building materials, plastics and paper, and methods of applications. (211)

Flame-Spraying Plastic Coating. Linde Air Products Co., 8 pp, ill, No. F-7789. Equipment, plate preparation, application technique and safety precautions for flame-spraying polyethylene plastic. (212)

MANUFACTURERS' LITERATURE

Barrel Finishing. Lord Chemical Corp., 32 pp, ill. Introductory bulletin describes various compounds for precision barrel finishing. (200)

Protective Coatings. Magic Chemical Co., 22 pp. Applications and methods of use of Magic-Vulc anti-abrasion and anti-corrosion plastic rubber coatings. (213)

Metallizing. Metallizing Co. of America, 20 pp, ill. Describes metallizing process and its usefulness in fighting corrosion, rebuilding worn parts, and reclaiming mismachined castings. (214)

Black Oxide Coating. The Mitchell-Bradford Chemical Co., 4 pp, ill, No. MB-3. Six advantages of Black Magic (Type A) Black Oxide Coating process for steel and iron. (215)

Micropolishing. The Murray-Way Corp. Engineering specifications and auxiliary equipment needed for micropolishing. (216)

Zinc Dust Paints. New Jersey Zinc Co., 36 pp, ill. Characteristics and uses of zinc dust paints, most adherent paints for galvanized iron and steel zinc. (217)

Aluminum Cleaner. Northwest Chemical Co., 10 pp, ill. Attractively presents information on the Alkalume Process for preparing aluminum for spot welding. (218)

Power Brush Finishing. Osborn Mfg. Co., 12 pp, ill, No. L-272. A comprehensive article covering the important factors in the selection and application of brushes for specific finishes. (219)

Batch Blasting. Pangborn Corp., 12 pp, ill, No. 223. Dimensions and specifications of both the 6- and 12-cu-ft Blastmaster Rotoblast for batch blasting in cleaning castings, forgings and heat treated parts. (220)

Rust Resistant Coating. Parker Rust Proof Co., 12 pp, ill. Discusses the use of Bonderite. a rust resistant coating, as an aid in cold forming. (221)

Vapor Degreasing Equipment. Phillips Mfg. Co., 21 pp, ill. Handbook gives a detailed description of vapor degreasing process, the materials used, its applications, advantages and limitations. (241)

Polyvinyl Chloride Coating. Quelcor, Inc., 4 pp, ill, No. 53A. Polyvinyl chloride coatings fused and flowed on metal for corrosion protection. (222)

Aluminum Coating. Royston Laboratories Inc., 2 pp, ill. Discusses Royalac Aluminum, a high quality industrial aluminum coating with the newly developed nonspattering feature. (242)

Corrosion Resistant Coating. Specialty Coatings Inc., Div. of Thompson & Co., 6 pp, ill. Examples of how Vinsynite Pretreatment was used in finishing six different types of metal products for good paint adhesion and corrosion resistance. (223)

Heat Treating • Treating

Heat Treating. Ajax Electric Co., Inc., Frankford and Delaware Aves., Philadelphia 23, Pa., 72 pp, No. 116. Detailed data on various methods of heat treating metals in this firm's salt bath furnaces. Request on company stationery direct from Ajax.

Induction Furnaces. Ajax Engineering Corp. Information on Ajax-Tama-Wyatt induction furnaces for melting metals with accurate temperature control and freedom from contamination. (224)

Case Hardening Process. American Gas Furnace Co. Principles of "Ni-Carb" case-hardening, its advantages, and descriptions of AGF furnaces for the process. (225)

Ovens and Heaters. Burdett Mfg. Co., 11 pp, ill. Covers sheet metal designing and production facilities of this firm—including ovens, heaters, spray booths and washers. (226)

Heat Treating Slide Indicator. Carpenter Steel Co. Indicates heat treatments recommended for various tool and die steels and effects of drawing temperature on hardness. (228)

Recirculating Furnaces. Despatch Oven Co., 12 pp, ill, No. 81. Shows a variety of Despatch recirculating furnaces in operation on different heat treating applications. (229)

Molten Salt Baths. E. I. du Pont de Nemours & Co., Inc., Electrochemicals Dept., 82 pp, ill, No. A-3294. Third edition of a complete guide in the use of molten salt baths for heat treating and case hardening. (230)

Articulated Hearth. Fahralloy Co., No. 112. Illustrates the Fahralloy articulated hearth of segmental design that permits replacement of any section instead of replacing entire hearth. (253)

Atmosphere Generators. Gas Atmospheres Inc., 6 pp, ill, bulletins N-452 and 1-552. Brochures describing the features and applications of insert atmosphere generators and nitrogen atmosphere generators. (231)

Rotary Hearth Furnaces. Gas Machinery Co., 4 pp, ill, No. A-102. Complete specifications of the Gasmaco rotary hearth furnaces for forging, annealing, heat treating or drawing operations. (232)

Electric Furnaces. Harper Electric Furnace Corp., 4 pp, ill, No. 252. Presents features and specifications of furnaces for all types of research and small scale production. (233)

Furnaces. C. I. Hayes Inc., 44 pp, ill, No. 112. Complete data on a variety of furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating, as well as on atmosphere generators and ammonia dissociators. (234)

Electric Furnaces. Hevi Duty Electric Co., 2 pp, ill, No. IND-1147EE. Includes specifications of the Hevi Duty Speed-Treet electric furnace, a high temperature furnace designed for the heat treating of high-speed steels. (235)

Tube Elements for High Temperature Furnaces. Kanthal Corp., 9 pp. Applications, construction and specifications of Kanthal tube elements for high temperature furnaces used in ceramics, chemical, glass and metal industries. (236)

Surface Hardening Stainless Steels. Lindberg Steel Treating Co., 24 pp, ill. Complete data on the Malcomizing process for surface hardening stainless steels. Seven case histories are included. (237)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on pages 261 and 262

Hole Quencher. Palmer Mfg. Co., 4 pp, ill. Features advantages of using the I. D. hole quencher for case hardening holes seven times faster. (238)

Liquid Carburizing. Park Chemical Co., 4 pp, ill, No. 82. Physical properties and applications of a water soluble liquid carburizing material. (239)

Electric Furnaces. Pereny Equipment Co., 3 pp, ill, No. 4A. Booklet tells advantages and illustrates typical group of this company's furnaces and kilns and their uses. (240)

Quenching Oils. Sun Oil Co., 8 pp, ill, No. A-2658. Complete data on Sun quenching oils, which can handle 95% of all quenching jobs in industrial heat treating. (243)

Portable Base Convector Furnaces. Lee Wilson Engineering Co., Inc., 19 pp, ill. Features and advantages of the new portable base single-stack furnace. (244)

Welding • Joining

Brazing Alloys. The American Platinum Works, 46 pp, ill. Handy-sized manual gives detailed description of the brazing process, the alloys used, design of joints and other considerations for successful joining. (245)

Welding Analyser. Brush Development Co., 2 pp, ill. Brief description of features, uses and advantages of the new Brush welding analyser, Model BL-213. (246)

Fastening Pins. C. E. M. Co., 4 pp, ill. Advantages and examples of how Spirol Pins overcome the inherent short-comings of fastening pins due to their spiral cross-section. (247)

Glass Joints. Cerro de Pasco Corp., 2 pp. Instruction sheet for making glass-to-glass and glass-to-metal seals with indium and tin solder. (248)

Welding Cost Calculator. Champion Rivet Co., slide indicator. Shows the costs for welding materials using various types of fillets and joints, and estimates the various factors effecting the cost. (249)

Welding Positioners. Cullen-Friestadt Co., ill. Catalog shows line of hand or power operated welding positioners with capacities up to 30,000 lb. (250)

Fasteners. Elastic Stop Nut Corp. of America, 29 pp, ill. A collection of many fastening problems with solutions. (252)

High-Speed Heating. Gas Appliance Service Inc., 8 pp, ill. Profusely illustrates a variety of furnaces for high-speed heating, such as applied localized hardening, annealing, brazing and soldering. (254)

Resistance Welding. General Electric Co., 16 pp, ill, No. GEA 4816. Analysis of resistance welding and a catalog of resistance welding equipment. (255)

Silver Brazing Alloys. Goldsmith Bros. Smelting and Refining Co., 25 pp, ill. Data sheets on silver brazing alloys include sizes, price, shipment and assortments. Also contains list of typical applications. (256)

Brazing. Handy & Harman, ill, No. 54. "Brazing News" describes applications and developments of Easy-Flo and Sil-Fos low temperature silver brazing alloys. (257)

Fastenings. H. M. Harper Co., 8 pp, ill, Vol. 17, No. 1. "Harper Bolt News" is published in the interest of users of rust and corrosion resisting fastenings. Features

MANUFACTURERS' LITERATURE

flood control units, bubble caps and trays, and part one of article on corrosion resistant fastenings. (258)

Stud Welding. KSM Products Inc., 7 pp, ill. Portable and permanent installation production equipment for welding studs to plates. (259)

Induction Heating for Brazing. Lepel High Frequency Laboratories Inc., 8 pp, ill. Details on induction heating units for accelerated brazing of parts. (260)

Arc Welding Equipment. Lincoln Electric Co., 2 pp, ill, No. 1304. Gives construction and specifications of engine-driven Shields-Arc SAE welder. (261)

Rivets. Milford Rivet & Machine Co. A handy slide rule selector gives complete rivet specifications. (262)

Snap Nut Fasteners. Prestole Corp., 2 pp, ill, No. 8000-A. Features specifications of three types of Prestole self-locking fastening units, available in all standard metal finishes. (263)

Adjustable Fasteners. South Chester Corp., Southco Div., 4 pp, ill. Describes adjustable door fasteners for machinery doors. Said to be applicable quickly and resist loosening due to vibration. (264)

Self-Locking Nuts. Standard Pressed Steel Co., 4 pp, ill, No. 866-153. Properties and applications of various Flexloc self-locking nuts that lock and stay put on a threaded member. (265)

Nut Fasteners. Tinnerman Products Inc., No. 326. Describes wide variety of speed nut and clip fasteners, said to be adaptable for most types of material or to all thread systems. (266)

Forming • Casting • Molding • Machining

Maintenance of Cutting Tools. The Carborundum Co., 72 pp, ill, No. 10. Helpful booklet on proper methods for keeping alloy and high-speed cutting tools sharp by grinding. (267)

Springtites and Sems. Eaton Mfg. Co., 4 pp, ill, folder C-49a. Thread cutting and self tapping springtites and sems. Dimensions. (268)

Electron Arc Drill. Elox Corp. of Michigan, 3 pp, ill. Discusses operation, cost of operation, and gives advantages and specifications. (269)

Powder Cutting Stainless Steels. National Cylinder Gas Co., 6 pp, ill, No. N-150. Complete data on the NCG Ferrojet process of powder cutting stainless steels. (270)

Inspection • Testing • Control

Laboratory Chemicals. Allied Chemical & Dye Corp., General Chemical Div., 264 pp, ill. Catalog of laboratory reagents and chemicals describes their properties, specifications, storage, packaging and other data. (271)

Test Chambers. American Research Co., 4 pp, ill. Describes the basic environmental test chambers produced by this company for testing under a variety of conditions. (272)

Optical Aids in the Metal Working Industries. Bausch & Lomb Optical Co., 16 pp, ill, No. D-22. Includes specifications of a complete line of Bausch & Lomb optical aids in the metal working industries. (273)

Portable Hardness Tester. Blosjo Enterprises, 4 pp, ill. Lists the many advantages of using the Blosjo Porta-Brinell hardness tester. (274)

Photoelastic Stress Analysis. Eastman Kodak Co., 16 pp, ill, price 35¢. Booklet briefly describes photoelastic stress analysis as a method of solving problems of stress distribution. (275)

Temperature Control. Illinois Testing Laboratories, Inc. Description, wiring diagrams and applications of Alnor Pyrotac excess temperature cut-off. (276)

Micro Hardness Tester. Kent Cliff Laboratories, 4 pp, ill, No. K-52. Complete data on the Kentron micro hardness tester that applies dead weight loads from 1 to 100 grams. (277)

Nondestructive Testing Machine. Magnaflux Corp., 4 pp, ill, No. 16,001. Operating principle, advantages and applications of Duovec magnetic particle testing machines. (278)

Time-Temperature Control. Minneapolis-Honeywell Regulator Co., Brown Instrument Div., 13 pp, ill, No. 6020. Shows features, design characteristics and specifications of cam programmer thermometers. (279)

Radiation Pyrometer. The Pyrometer Instrument Co., No. 100. Features and principle of Pyroradiation pyrometer for obtaining spot temperatures in furnaces, kilns, forgings and fire boxes. (280)

Thermocouples. Arklay S. Richards Co., Inc., 16 pp, ill, No. 5. Description, specifications and advantages of this company's thermocouples and thermocouple accessories. Includes information for ordering. (281)

Impact Testing Machine. Riehle Testing Machines Div., American Machine & Metals Inc., 6 pp, ill, No. RM-8-52. Booklet gives operating features and specifications of the Riehle Model PI-2 impact testing machine. Also illustrates other Riehle testing machines. (282)

Ultrasonic Thickness Gage. Sperry Products, Inc., 4 pp, ill, No. 3700. Description and basic theory of Reflectogage ultrasonic thickness tester and flow detector. (283)

Pyrometer Wire Color Codes. Thermo Electric Co., Inc. Handy chart gives pyrometer color codes, calibration symbols and parts meeting ISA, military and aeronautical specifications. (284)

Impact Tester. U. S. Testing Co., Inc., 2 pp, ill. Includes history, description and use of the SPI low temperature impact tester. (285)

General

Flock. Cellusuede Products Inc., 12 pp, ill. Uses and method of application of decorator flock. Includes explanation of adhesive selection and application. (287)

Decimal Equivalent Chart. John Hassall, Inc. Easy-to-read decimal-equivalent wall chart of this company's cold headed parts. (288)

Materials Controls. Remington Rand Inc., No. KD367. Booklet describes Kardex system for keeping visible materials and parts inventories coordinated with production. (289)

Industrial Chilling Equipment. Sub-Zero Products Mfg. Div., Deep Freeze Distributing Corp., 8 pp, ill. Specifications and uses of industrial chilling machines for shrinking, testing and treating of metals. (290)

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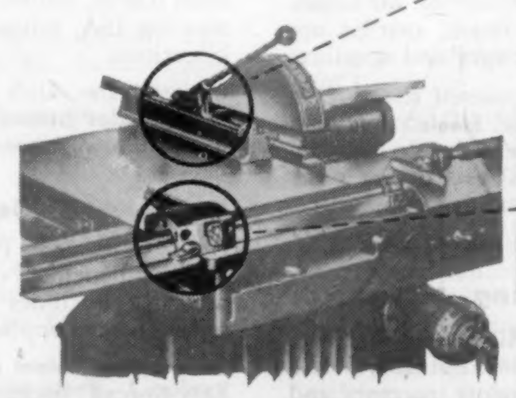

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The Last Word

Not Enough

As we keep telling you,, and anyone else that will listen, there is more than one way to skin a cat. We say, at the drop of a hat, that if you can't find a better material to do a job, find a better way of using the material you do use. U. S. Rubber Co. has done just that. Obviously, golf balls must be made of rubber. So the problem keeps arising as to how to help the dubs like you and me get greater distance with those wild swings we call drives. These friends of editors and golfers have found one solution. They now mark the golf ball covers with diamond shape indentations rather than the old familiar dimples. The result? An added 10 yards to the average drive. That's all very nice, but what about the last few feet when the ball should go in the cup. Will diamonds help that? Radar might be better.

Signs

IBM started it all. For years their offices have been plastered with signs reading "THINK". Cartoonists have had a field day with it and one of them recently offered a substitute word "SCHEME". Some people do. To relieve the Spartan simplicity of our editorial office we recently added a sign which makes people think—and then laugh. It reads:

NOTICE
While In This Office
Speak In A Low, Soothing Tone
and
Do Not Disagree With Me In Any Manner
Please be informed that when one has reached "my age" NOISE and NON-CONCURRENCE cause gastric hyper-peristalsis, hyper-secretion of the hydrochloric acid, and rubus of the gastric mucosa. . . . . . and,
I BECOME MOST UNPLEASANT!!!!!

We are indebted for this gem to Louie, boniface of the Scribe's Restaurant where the best steaks in New York are to be had.

And Coming

Speaking of scheming, our editors (en masse) have been doing that for several weeks to get out a special article which will grace our May issue. Scheming was required to extract, from plants throughout the country, secrets on how to reduce the costs of products through better selection of materials or materials forms. The 150 cases ±10% which will be presented should provide plenty of food for thought for anyone interested in saving money. That should include all of us.

Language Hash

Elements of fine European languages have been mixed together to attain a new international language that is intended to be seen and not heard. English, French, Italian, Spanish and Portuguese have all contributed to *Interlingua* which was developed as a means through which scientists of any of these nationalities can read what is going on in other countries even though they don't understand the native tongue of the author. A sample is given in the Armour Research Foundation *Industrial Research Newsletter.* Here it is: "Scientistas e technologistas es dar le mundo un nove median de communication—un ligua appellate 'Interlingua'." It's not hard to read, but if you give up, here's the translation: "Scientists and engineers are giving the world a new medium of communication—a language called 'Interlingua'." Already there are some books and periodicals in the new technical language. Could be better than pidgin english.

Last Warning

If you haven't already done so, make arrangements to attend the Second Basic Materials Show and Conference. The Dates: May 17, 18, 19, and 20. The Place: International Amphitheatre, Chicago.

It's Simple

As many of you television fans know, there have been many problems in producing television cabinets. Wood has been expensive. Therefore early attempts have been made to have metal and plastics cabinets look like wood with varying success. Many engineers feel that metal cabinets offer the best prospects for lowest cost cabinets. After a complete cycle of thinking during which metal was finished in simulated oak or mahogany, a simple solution was evolved—permit the steel to look like steel. I haven't seen one yet, but the steel cabinets with the *au naturel* finish are said to blend in well with other living room furnishings.

T. C. Du Mond
Editor